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SOAP BUBBLES OF LONG DURATION.*

BY

SIR JAMES DEWAR, LL.D., D.Sc., F.R.S.

Fullerian Professor of Chemistry, Royal Institution, Honorary Member of the Institute, Franklin Medalist, 1919.

An investigation of the properties of soap bubbles is the logical outcome of the experiments on flat liquid films described in the 1916 Friday Evening Discourse. Some fifty years ago Joseph Plateau—Professor of Physics at Ghent—began a series of investigations on Surface Tension Phenomena, and for nearly forty years carried out a number of wonderful investigations, although practically blind, owing to an accident which occurred while examining the action of intense light on the retina in the early part of his career. It is due to the fascinating character of his pioneer work on soap bubbles that the study has been continued. Since the work of Plateau, great advances have been made in the experimental study of Surface Tension Phenomena by Dupré, Mensbrugghe, Reinold and Rücker, Michelson and his collaborators. The theoretical advancement which science owes to Willard Gibbs dominates all modern research on capillary phenomena.

The flat films described last year were developed in an exhausted atmosphere of nearly pure water vapor; while soap

* Communicated by Sir James Dewar. Lecture delivered before the Royal Institution and later to appear in its Proceedings.

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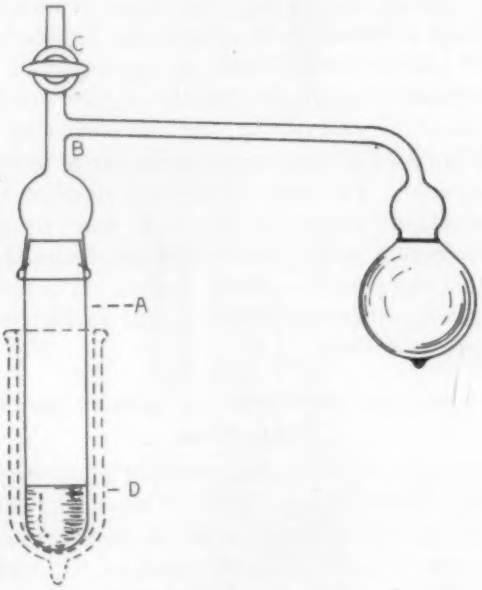
bubbles are blown up with air in air. Experiments extending over a year have proved that in order to keep soap bubbles for any length of time the air must be free from deteriorating gases and suspended solid matters. The presence of living organisms and their spores amongst the finely divided organic and inorganic particles in the atmosphere was discovered by Pasteur. He purified the air by passing it through a red-hot platinum tube containing platinum gauze, afterwards removing the total carbonic acid. Later Tyndall used a concentrated beam of light to demonstrate the presence of floating impurities in the air, as a test of "optical emptiness." Tyndall passed a parallel beam from an arc lamp through a large plano-convex lens, which condenses the light into a cone, at the apex of which the intensity of the illumination causes the floating matter in the air to be easily recognized. If a Bunsen or hydrogen flame is placed below the focus, the reflected light gradually disappears as the floating material, being largely organic, is burnt and passes into the gaseous state. Another method used by Tyndall to obtain a dust-free space was by smearing the interior surface of a glass box with glycerine, closing and allowing it to stand for a few days, when the dust settled, adhering to the glycerine. On applying the light beam test, the box was found to be what Tyndall termed "optically empty." Aitken has devised an apparatus for counting the particles in the air, suggested by experiments on cloud condensation due to the cold produced by sudden expansion of air saturated with water vapor. Very briefly his method is to make these solid particles the nuclei of small raindrops, which can then be counted. Ordinary London air contains about 100,000 suspended particles, organic and inorganic, per cubic centimetre. The particles get coated with all kinds of adherent organic matter which, coming in contact with the bubble, affects its surface tension locally, thereby inducing instability.

When bubbles blown with pure air were formed in vessels closed to prevent communication with the outside air, it was soon recognized that, when the interior of the vessel had become free from suspended matter by long standing and deposition on the walls the surface of which was coated with glycerine soap solution, the bubbles lasted much longer.

The methods of purification employed for the purpose of obtaining long-lived soap bubbles were (1) simple displacement by

purified air; (2) deposition of the solid material by electrical discharge in the space to be utilized. To demonstrate the two methods, domed glass shades about 2 feet high were used, each with a black wood base, in which was a circular glass window. A concentrated beam of light from an arc lamp was reflected up through the window, thus strongly illuminating the solid impurities in the air-space enclosed by the shade. Highly compressed air from an ordinary steel bottle, purified by passing it

FIG. 1.



through three small glass towers containing, respectively, soda, lime, and cotton-wool damped with glycerine, was introduced in the bottom of the shade through holes in a circle of lead pipe secured on its wooden base. In about a minute the beam disappeared as the impure air was swept out through a small hole in the top of the shade. To show the electrical method of purification a similarly fitted shade had an insulated steel point hung within it from the centre of the dome. This was connected to one pole of a Wimshurst machine, while the other was earthed along with the lead pipe described above. Within two minutes of starting the point-discharge the illuminated cloud had practically

disappeared. When this treatment was applied to a vessel containing soap solution, a heavy mist of large floating water particles first appeared, of some persistence.

BUBBLES FROM THE EVAPORATION OF LIQUID AIR.

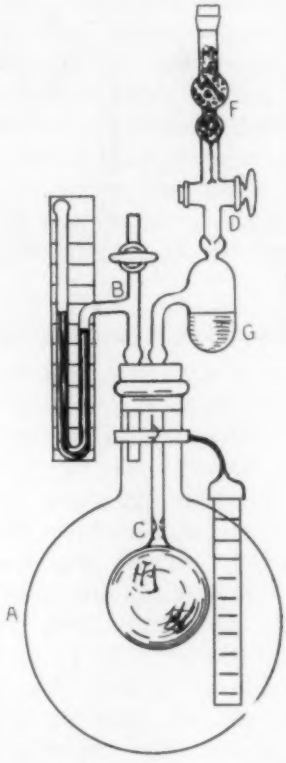
The evaporation of liquid air readily affords a supply of pure mixed oxygen and nitrogen. Apparatus for this purpose is shown in Fig. 1. The liquid air is contained in a tube, *A*, which is fitted by a ground cap to the delivery tube, *B*, and placed in a vacuum vessel, *D*, to control heat influx. At *B* one branch tube leads to the thistle-shaped funnel from which the bubble is to be suspended, while another branch leads to the stop-cock, *C*, by means of which the admission of air into the bubble can be regulated. The cavity above the ground cap, and the horizontal tube leading to the bubble are packed with copper-wire gauze in order to warm the air evaporated. The soap solution is supplied to the mouth of the thistle-shaped funnel in the usual way: or otherwise, by having a constriction in the tube above the thistle-shaped funnel, together with a stoppered dropping funnel. It is thus possible to fill the constriction with soap solution, and develop bubbles singly or in succesion, as desired.

APPARATUS FOR THE PRODUCTION OF BUBBLES UNDER VARIOUS PRESSURES.

The apparatus (Fig. 2) is a spherical glass flask, *A*, of 2½ litres capacity, fitted with an india-rubber cork which has been previously cut and steamed in order to remove volatile organic matter. The tube, *B*, leads from the vessel, *A*, to a mercury U-tube manometer, and to the stop-cock to which the air-pump is attached; while another tube carries at its lower end the constriction, *C*, and the funnel on which the bubble is to be formed, and at the upper end the small reservoir, *G*, of soap solution. Air passing through the purifying bulbs, *F*, is admitted by the regulating stop-cock, *D*, through the reservoir, *G*, to the funnel-mouth, *C*. A capillary tube between *D* and *G* assists in the control of air when the pressure in *A* is very small. By slightly tilting a few drops of the solution in *G* down the tube to *C*, bubbles are easily blown within the flask, *A*, even at a pressure less than 1 mm. Hg. At this pressure the contraction of the bubble proceeded visibly, and was accelerated as the diameter was reduced.

In Fig. 3 various forms of bubble-support tubes are shown, convenient for different purposes: (*a*) permits the insertion of a long fine tube or rod into the bubble; (*b*) allows the apparatus to be inverted, without loss of soap solution, so as to have the bubble supported from below; (*c*) permits the formation of

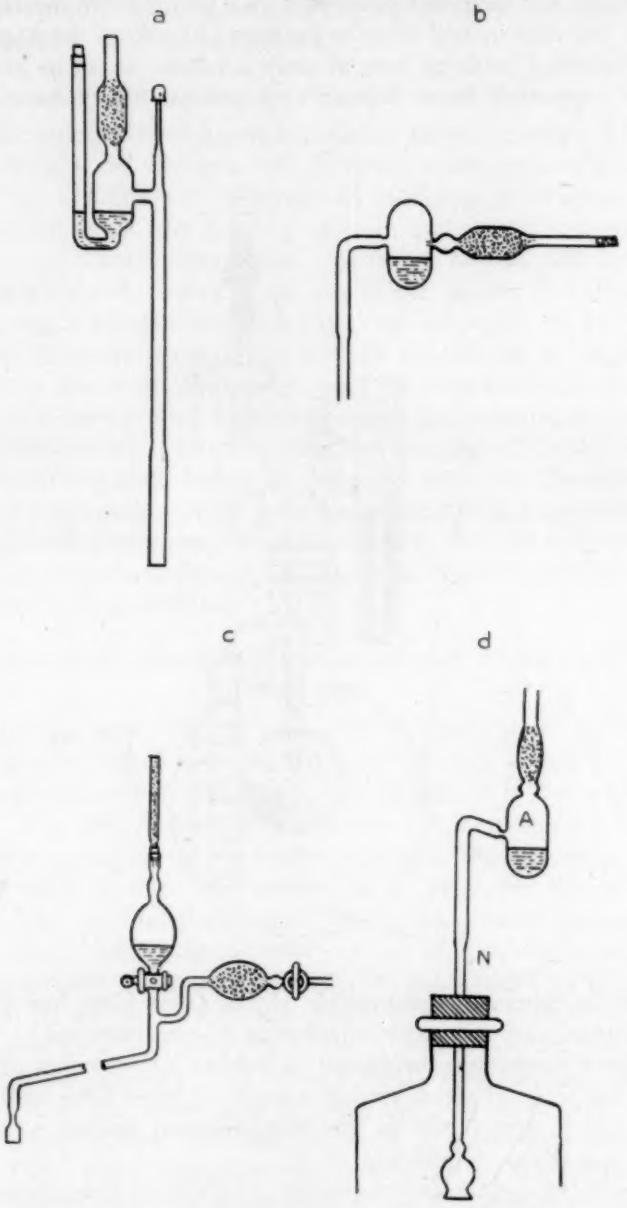
FIG. 2.



bubbles in otherwise inaccessible places (this form has a dropping funnel and stop-cock attachment to the reservoir); (*d*) is useful for forming a succession of bubbles (by a series of slight regulated jerks of the reservoir, a series of films form in its exit-tube, which pass down to the thistle-shaped funnel, and there produce a chain of bubbles).

An ordinary tubulated aspirator, of about 12 litres capacity, is

FIG. 3.



very convenient for the study of bubbles up to nearly 20 cm. in diameter. For careful measurements a plane-sided vessel is necessary to prevent optical distortion. For this purpose a metal-framed plate-glass box, 1 foot length of side, was used. The sheet of glass forming the top was nearly 6 mm. thick; it was pierced with three or four holes from ½ cm. to 3 cm. diameter, besides the central hole, 3 cm. in diameter, for supporting the blowing tube. These extra holes allow the admission of flexible glass supporting rings, or draining points, where necessary. Thus, by means of the dropper (Fig. 3*a*), a fine glass thread or wire can be passed down through the bubble, so that the drop is removed and the distortion observed. Similarly, through one of the openings in the lid of the cubical glass chamber, a thin glass rod with an up-turned end, approaching the bubble from below, can be employed to drain off any excess of liquid, and thereafter to determine the changes effected in the vertical and horizontal diameters.

DISTORTION OF BUBBLES, HANGING OR SUPPORTED.

The following instances show the amount of distortion or ellipticity, present in hanging bubbles, under different conditions:

A bubble, 19.1 cm. vertical diameter, 17.8 cm. horizontal diameter (ellipticity 7 per cent.), when freshly blown from solution of 5 per cent. potassium oleate, 50 per cent. glycerine, was only feebly colored, and therefore fairly thick. On the fourth day its vertical diameter was 18.1 cm., and on the fifth day 17.7 cm., being then sufficiently thinned to be well colored.

A bubble of 5 per cent. ammonium oleate in 50 per cent. glycerine, measuring 17.25 cm. vertically and 16.2 cm. horizontally (ellipticity 6 per cent.) was at first only feebly colored in the lower one-fourth. By the third day the vertical diameter was reduced to 16.6 cm. from the reduction of mass, shown by an intensification of the coloring. A bubble of this composition exposed to water vapor, by running water into the containing vessel, will condense and absorb the water vapor and become thickened again for a time. Such a bubble of 30 cm. vertical diameter was dragged down by the water it absorbed in one day to 31.8 cm., an elongation of 6 per cent.

A bubble, 11.2 cm. diameter, with the upper half black and lower half colored, was reduced to 10 cm. diameter, when entirely

black, by drainage—*i.e.*, a distortion of 12 per cent. vertically was caused by the lower half of a thin black bubble thickening to show color by adding a few drops of soap solution.

If instead of the bubble being supported from above it rests on a suitable light ring support, it will obviously decrease in vertical diameter when it becomes thickened and weighted. This was frequently observed with bubbles of about 40 cm. diameter, resting on a 10 to 12-cm. ring of thin iron wire.

With a water layer in the globe, considerable variations were noted from day to day, *e.g.*—

Thus, a bubble colored green and carmine, very brilliant but fairly thick, 42.6 cm. diameter, thinned to half black and half silvery (next thicker color to black), 43.6 cm. diameter.

Another bubble colored amber to purple, near lower limit of thickness to show color, 22.7 cm. diameter, thinned to all black (thinnest possible), 23 cm. diameter.

A colored bubble 43.3 cm. diameter, thickened in 15 minutes by condensation to 42.7 cm. diameter.

Bubbles of such a size flattened down on their supporting rings as they became thicker and heavier, and could be seen hanging over the ring-support from this cause.

A bubble 39 cm. diameter, hanging from a 4-cm. glass funnel support, thinned to over 70 per cent. black on its second day, and increased until its 63rd day, when it burst, 80 per cent. black. On five occasions a slowly accumulated drop was observed to fall off—namely, on the 6th, 10th, 20th, 27th, and 52nd days respectively. The alterations in diameter which thereupon resulted were as follows:

With drop	39.0	39.05	38.95	38.45	37.80 cm.
Drop fallen	38.5	38.55	38.40	37.90	36.95 cm.
Alteration	0.5	0.50	0.55	0.55	0.85 cm.

This bubble was blown from a solution containing 10 per cent. ammonium oleate and 50 per cent. of glycerine.

A bubble of similar size, but resting on a ring, varied in vertical diameter as follows:

42.6 cm. when fairly thick, at first.
43.5 cm. 15th day.
43.0 cm. 16th day, orange to amber.

43.3 cm. 17th day, 80 per cent. black.
43.0 cm. 18th day, four-fifths deep orange, one-fifth purple;

thus rising higher on its ring-support as it became thinner.

The maximum amount of distortion by loading which a bubble of this size can maintain was observed in one case by expanding the bubble until the distortion at the rim-support, 4 cm. in diameter, showed that it was nearly being dragged off. The dimensions were then 45.4 cm. vertically and 40.1 cm. horizontally (ellipticity 11.7 per cent.). The diminution in vertical diameter by the release of a single drop was 2.1 cm., showing the near approach to instability. After fourteen days the drainage reduced the loading of the bubble so that the vertical diameter became substantially constant, as shown by the following records:

Day	7th	14th	21st.
Diameter	44.3	41.6	41.8

After this date the bubble remained colored in the lower three-fourths of its area. In this condition the distortion caused by one drop was approximately 1 cm. The persistence of the colored stage could be maintained by a very minute continuous leak of solution from the reservoir into the supporting nozzle. When the soap solution supply was stopped, the development continued to the black state. When completely black the whole mass, in a bubble 40 cm. in diameter, is of the order of 50 mgms., so that the bubbles are very susceptible to disturbance from shock to the containing vessel. Local or sudden changes of temperature must also be avoided, as strong convection currents are thereby set up. Such currents become evident by innumerable silvery discs (see p. 738) streaming continuously in many directions over the black film. The thicker silvery discs floating for a time on a thinner black film represent excess of liquid drawn in either from the drop below or the ring of liquid, at the contact of the bubble with the supporting nozzle. By the use of closed vessels the nozzle is kept constantly moist, and this is probably a factor in the preservation of black bubbles.

DURATION OF LIFE OF VARIOUS BUBBLES.

The records of a large number of bubbles, up to 46 cm. in diameter, have been preserved. Some extracts are condensed in the following summary:

TABLE I.

*Lives of Various Bubbles.**

Three, 16–18 cm., 50 per cent. glycerine, 5 per cent. soap, water in vessel; temperature 10°–20° C.	28–42 days.
One, 14 cm., 50 per cent. glycerine, 14 per cent soap, water in vessel; half black at end; temperature 4°–11° C.	98 days.
One, 20 cm., 50 per cent. glycerine, 5 per cent. soap; temperature 9°–11° C.; over 60 per cent. black at end	95 days.
One, 12 cm., 30 per cent. glycerine, 3 per cent. soap; temperature 10°–20° C.	30 days.
Black horizontal film, 20 cm. diam., 50 per cent. glycerine, 5 per cent. soap; temperature 4°–20° C.	over 1 year.

* NOTE: A hanging bubble blown and kept in air saturated with water vapor, of a capacity of 4.5 litres, took 322 days to completely collapse from air transfusion.

TABLE II.

Life of Successive Bubbles. 40 cm. Bubbles on Ring.

1st 200-litre vessel		2nd 200-litre vessel
1st bubble (vessel dry)	3 days	1st, 5 days
2d bubble (water in vessel)	7 days	2d, few hours (ring rusty)
3d bubble (water in vessel)	10 days	3d, 3 days
4th bubble (water in vessel)	24 days	4th, 18 days
5th bubble (water in vessel, vibration)	19 days	5th, 11 days (hot weather, etc.)
6th bubble (water in vessel)	55 days	6th, 63 days (hanging on 4 cm. support)
7th bubble (water in vessel, out in yard, frosty at end)	31 days	7th, 42 days (globe became contaminated)

The first item of Table I includes the first bubble (50 per cent. glycerine, 5 per cent. ammonium oleate), which kept its color instead of developing to blackness. This was caused by moisture left after cleaning the 5-litre bottle in which it was blown; no more moisture than enough to give a bedewed appearance was left, but this distilled to different parts of the vessel, as the local temperature altered, and resulted in a movement of water vapor sufficient to keep the absorbent bubble thick enough to show colors.

Sharply marked zones of different colors are a feature of such bubbles. For this an undisturbed atmosphere is necessary; otherwise convection currents in the bubble will, by continual mixing, prevent the quiet development of separate color zones. The temperature alterations must, therefore, be small. From the records of one bubble the following appearances were noted:

On the 15th day. 20 cm. in diameter: sharp boundary line at "60° N. Lat." between steel-blue above and greenish-yellow below: similar boundary between blue-green and blue-purple at "50° S. Lat." Large drop on bubble.

On the 18th day. Diameter, 19.4 cm.: three sharp line boundaries: green to purple at "30° N.": dark green to light green at "70° S.": light green to thin magenta at "80° S.": intense green disc at lowest part. Drop fallen off.

On the 24th day. Main area of bubble fairly uniform red-purple: boundary at "75° N." to pale green above, and to deep green below at "60° S." Graded Newton's rings of mauve and green below this.

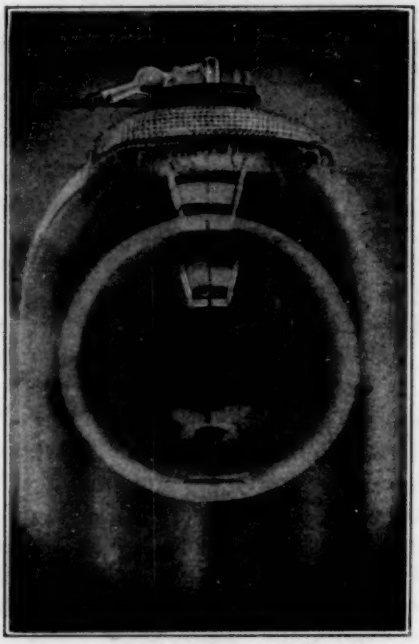
The life of the bubble shown in the second item of Table I was double that of those in the first item, namely, 98 days instead of about 40 days. The solution used had 10 per cent. of ammonium oleate instead of 5 per cent. as before. This factor, however, had less influence than the generally lower temperature of under 11° C. instead of up to 20° C. as before. Between the 75th and 95th days there was a contraction from 11.4 cm. diameter to 10.4 cm., while still remaining colored. By the 95th day the bubble had become too dilute to maintain any color, and accordingly developed to the thinnest or "black" stage in the upper half. On the night of the 98th day the temperature of the Laboratory fell to near freezing point, and the bubble did not survive this change.

The next item refers to a bubble of 5 per cent. potassium oleate in 50 per cent. glycerine. The 12-litre aspirator in which it was blown was well dried, and, further, was placed in a vault where only slow and small temperature variation occurs. In three months the variation was from 9° C. to 11° C. This solution was chosen because of its property of giving extremely slow development to the "black" stage. The result was that in 95 days the zone of black had only extended down to "25° S. Lat.," the remainder being so thick as only to be feebly colored with faint pink-and-green rings, probably up to a hundred times the thickness of the black supporting zone above. The final collapse may have been associated with this condition; moreover, the potash soap is very sensitive to slight alkalinity of the glass—no other disturbing cause was observed.

Table II shows the lives of two sets of large bubbles under

similar conditions, in two vessels of 200-litre capacity (Fig 4). These vessels were cylindrical glass globes, used in the Laboratory twenty-five years ago in the production of liquid ethylene. They had short necks, 14 cm. diameter, which were fitted with good, cleansed india-rubber corks to carry the blowing tubes, vent tubes, etc. An oxidized steel wire ring was used to support the

FIG. 4.



majority of the bubbles. These rings were about 12 cm. diameter, and were raised, by three supports of the same oxidized wire, to about 25 cm. above the bottom of the globe. For bubbles so supported the blowing tube was less than 1 cm. diameter; it had a constriction of about 1 mm. bore, a few centimetres above the lower end. A few drops of liquid from the reservoir above were decanted down to fill the constriction for the purpose of starting the bubble. The reservoir is shut off by a stop-cock from the blowing tube, as it is not advantageous for the soap solution to be exposed to the current of air used in expanding the bubble:

a side tube is sealed in for the air inlet. The blowing tube is mounted, so that it can slide up and down while remaining air-tight. A few small bubbles are first blown and run round the supporting ring to wet it. A bubble is then blown to about 4 cm. greater diameter than the ring, while resting on one side of it. This is done by holding the end of the blowing tube sufficiently out of the centre, and steadily raising it until the bubble is about 15 cm. diameter, when it is allowed to come into full contact with the whole ring, and the expansion is continued until the requisite diameter of about 40 cm. is reached. Meanwhile, the blowing tube is continually raised through its sliding support tube in the india-rubber cork, and finally withdrawn by a to-and-fro spiral movement upwards. In one case when the bubble became free from the tube, a complex up-and-down oscillation took place in a period of about two seconds, and with an initial amplitude approaching 3 cm. at the upper periphery. By leaving the blowing tube in the bubble the advantage of an added steady support is secured; this is unsatisfactory when measures of contraction are being made, but it certainly helps to prevent undue disturbance, especially in the early stages, when the bubble is liable to be thick and somewhat top-heavy on the 10 cm. ring.

It can be seen from Table II that there is a general increase in length of life of the successive bubbles in both the first and second vessels. The last items, in both cases, show a shorter life; this, however, was due in one case to the vessel being in the open air in winter, whereby its temperature at the end went below freezing point; and in the second case, to the globe becoming contaminated, from the displacement of a badly fitting tube. The irregularity between the fourth and fifth items was explained by the hot weather (temperature over 20° C.).

The maintenance of color in such large bubbles was not easy. For this purpose a good circulation of water vapor in the vessel seems desirable, as the mere presence of a litre or two of water in it was not entirely effective. A wet cloth placed on the upper part of the vessel (seen in Fig. 4) by its own evaporation maintained a slightly cooler area, thus promoting the condensation there of drops of water. A flow of water vapor up through the vessel was thus obtained, which being partly absorbed by the glycerine in the bubble did for a time maintain, and even increase, its thickness and color. In the later stages also, when the bubble material

has thus become altered in the relative proportions of its constituents, vaporization from the bubble may take place, and then the opposite effect is observed; distillation causing the thickness to decrease, so that two or three colors are passed through in as many hours. A few degrees rise of room temperature causes the same change, especially in diluted bubbles. The lowering of the temperature will then reverse the effect and the bubble is seen to thicken. The ordinary variations from night to day are sufficient to cause many such repetitions in the same bubble. Thus, when it was thought to increase the proportion of water vapor by warming the water in the vessel, and thereby increasing the thickness by a greater absorption, the rise of temperature counteracted any increased absorption; and once more the bubble became thinner. The removal of the wet cloth allows the condensed water to distil off more vapor, which is often sufficient to thicken the bubble. This is best seen when a good condensed deposit is accumulated before blowing the bubble, as was done in one case (see fifth bubble, first vessel) by the application of bags of ice. The bubble, which was then blown, remained almost entirely colored throughout its life. A small zone of black came and went, and the thickness was reduced once or twice by a damp cloth. The weather was rather warm at first, but became more temperate (the time was August). Finally, the bubble was very much thickened, and probably burst from this cause; for as the bubble became thick, it overhung the ring unsymmetrically, and most probably became lopsided enough to swing round and touch the vessel. The supporting ring was seen to be slightly out of the horizontal, and in vibration due to the working machinery in the room below.

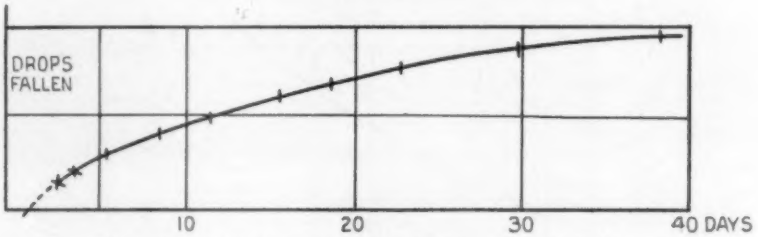
The fourth bubble in the second vessel: during the first week untouched; maintained green and pink color; thick and overhanging the ring; then frequently treated by damp cloth above, thinned while cloth was on and thickened when cloth was removed; at third operation, bubble half black; next time, the water below was warmed by the arc lamp beam: result, 85 per cent. black obtained.

The fifth bubble in the second vessel lasted eleven days only; short life in the hot weather; disturbed at the end by damp cloth, also by vibration; thinned to silver and black; first three days thickened rapidly by absorption from the deposit of water; im-

mediately after being blown sagged over ring; then steadily thinned through several beautiful grades, until on the fifth day at 19½° C. it was amber and purple, with silver above. Damp cloth then put on; the silver extended all over, followed by a fairly uniform development of black. Two grades of black were noted—the deepest black being only a zone of a few centimetres at the top. The top of the bubble was approximately 1 cm. higher when black than when thick and heavy.

The sixth bubble in the first vessel went quickly black in two days (possibly from an unusual excess of ammonia in the soap solution), and remained so until the end of the first week. It then thickened to various colors for four weeks, and once again went

FIG. 5.



Absorption of water vapor by a 40 cm. bubble. Rate of fall of drops.

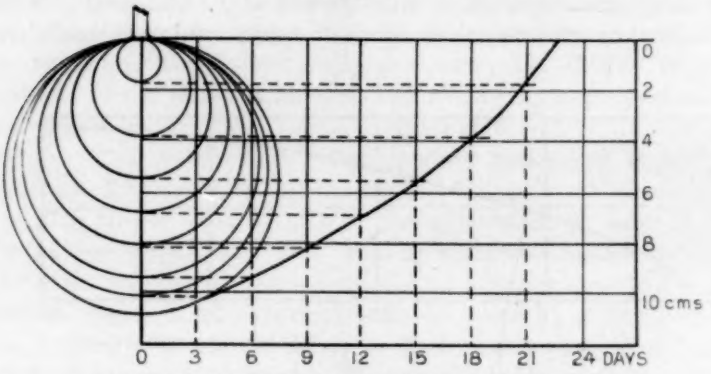
quickly black. This condition remained for three weeks, during which time a steady diminution of diameter was measured. The blowing-tube having been left attached to the bubble, the contraction had by time narrowed down the upper part of the bubble till it became a neck. When this divided, the disturbance was probably more than the very dilute and very thin film could survive, for the next morning it had gone.

The seventh bubble in the second vessel was suspended from a 4-cm. nozzle; it lasted from October 27th to December 9th. The temperature fell from 15° C. at first to below 10° C. after the first week. The bubble burst after a sudden rise of temperature from 6° to over 9°, accompanied by a considerable fluctuating fall in the barometer, when it was found, by the optical test, that the air in the globe had become contaminated. This bubble afforded an opportunity for observing the rate of fall of condensation drops. Excluding the preliminary drainage, the results are shown in the annexed diagram (Fig. 5).

GAS TRANSFERENCE THROUGH BUBBLES AT ATMOSPHERIC PRESSURE.

Long-lived bubbles regularly diminish in diameter, and most rapidly when thinned to "black." The contained air or other gas is at a somewhat higher pressure than the atmosphere in which the bubble stands, and therefore tends to pass out; with the result that there is a continual diminution in size. With black bubbles up to about 15 cm. the change becomes very evident in about a week. Using a cathetometer, the contraction can be observed accurately from day to day. The subjoined diagram (Fig. 6)

FIG. 6.



Black bubble in hydrogen. Decrease in size at 3-day intervals.

shows the contraction, measured every third day, of a black bubble in hydrogen. From an initial diameter of approximately 11 cm., by the twenty-third day it had completely contracted. It will be noticed that the rate of contraction was accelerated as the diameter decreased.

The gradational diminution in diameter of black bubbles made from soap solutions of different compositions, and with diameters up to 46 cm., was periodically measured with the cathetometer.

The rate of gas transference from within the bubble outwards at any time can be obtained directly from the mean daily reduction in diameter at that time, and is readily measured by dy/dx, the slope of the tangent drawn at the desired point of the contraction curve. The amount of the gas transference, in cubic centimetres per day through unit area, is then equal to one-half of the daily rate of reduction in diameter, measured in centimetres.

This follows directly from the simple properties of a sphere;

for if S and V be respectively the surface and volume, and D the diameter, then $S = \pi D^2$, and $V = \frac{\pi}{6} D^3$, so that $dV = \frac{\pi}{2} D^2.dD = \frac{1}{2} S.dD$, therefore dV/S, the rate of gas transference per unit surface, $= \frac{1}{2}.dD$, which is half dy/dx, the daily rate of reduction in diameter shown by the slope of the tangent already referred to.

Some of the results obtained are shown in the following Tables III, IV, V, and VI, in which are given respectively (1) the diameter of the bubble on which the measures were made; (2) the corresponding internal excess pressure, above the exterior air pressure, given in mm. water; and (3) the measured value of $dD/2$, representing, as shown above, the rate of gas transference in cubic centimetres per day passing out through each square centimetre of the bubble when at the diameter given in line (1).

Gas Transference Through Black Air Bubbles.

TABLE III.

Fifty Per Cent. Glycerine, 2½ Per Cent. Soap; Hanging on Glass Tube.

Diameter	6	7	8
Internal pressure	0.30	0.26	0.23
Gas transference rate	0.065	0.035	0.030

TABLE IV.

Twenty-five Per Cent. Glycerine, 4 Per Cent. Alcohol, 5 Per Cent. Soap; Hanging on Glass Tube.

Diameter	10	12
Internal pressure	0.18	0.15
Rate	0.15	0.11

TABLE V.

Two Large Black Bubbles (Thinned by Water Condensation); Hanging on a Glass Tube.

	I	II
Diameter	38	38
Internal pressure	0.057	0.057
Rate	0.023	0.015

The corresponding rates calculated for similar bubbles 10 cm. diameter would be: (1) 0.086; (2) 0.58; whereas a bubble subject to water condensation, but still retaining some color, contracted from 11 cm. diameter on its 75th day to 10 cm. diameter on the 95th day, being a diminution of 1 cm. in twenty days, giv-

ing an average daily rate of gas transference per unit of surface equal to 0.025 cm., or about one-third the calculated rate for a black bubble of the same diameter.

Table V may be amplified as follows, to show more completely what is occurring in bubbles of this size:

TABLE VI.

Gas Transference Through 38 cm. Black Bubbles in Air (Dilute Glycerine-Oleate Solution).

Results.		(I) 5 weeks black*	(II) 2 weeks black†
Diminution in diameter	Daily	0.045 cm.	0.03 cm.
	Total	1.58 cm.	0.41 cm.
Diminution in volume	Daily	0.103 litres	0.067 litres
	Total	3.60 litres	0.940 litres
Gas transference through each sq. cm.	Daily	0.023 c.c.	0.015 c.c.
	Total	0.805 c.c.	0.205 c.c.

* No. I, hanging on a glass tube, † No. II, less diluted than No. I, and resting on a steel-wire ring.

In the case of a hanging bubble as large as 38 cm., referred to in Table VI, the total reduction in the diameter amounts only to 1.58 cm. in five weeks. The volume of such a bubble is over 30 litres, and the surface has an area of 5000 square cm., while the total weight is only about half a gram. Being thinned to the "black" stage, it has a maximum thickness of approximately fifteen $\mu\mu$'s; that is to say, one and two-third million such films if superposed would have a total thickness of one inch. The internal excess pressure is of the order of a twentieth of a millimetre of water, or about one fifteen-thousandth part of the pressure of the atmosphere. Nevertheless, the actual volume of air which passed out of the black bubble in five weeks was 3.6 litres, or every minute a layer of air molecules some ten to eleven times the thickness of the wall of a black bubble of 38 cm. diameter passed through it. Hence, the thickness of the layer of air which at ordinary temperature passes through the film in one second is 10/60ths of the thickness of the film, or 2.5 $\mu\mu$'s—in other words, a layer of air as thick as the film would take six seconds to pass through it. Again, the mean free path in air is 100 $\mu\mu$'s, which is nearly seven times the thickness of the film, and therefore some forty times the thickness of the layer of air passing through the film in one second. Theoretically the internal pressure in a black bubble of less than about 1 cm. diameter would be sufficient to cause the transference of a layer of gas of a thickness equal to the length of

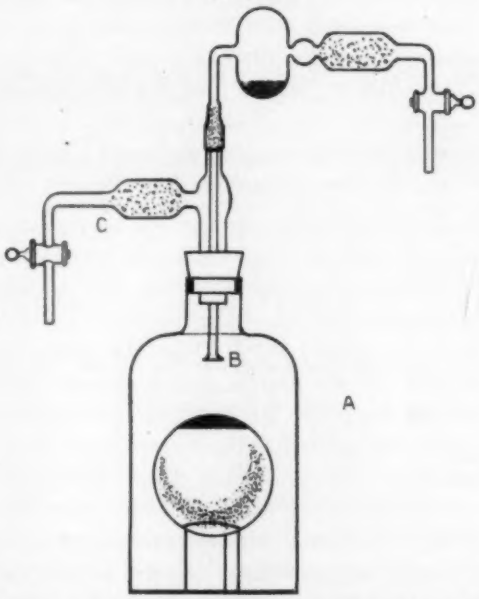
the mean free path. The rate of transference in bubble II is only about three-quarters of that in bubble I.

A black air bubble about 42 cm. diameter, supported by nozzle above and a small fixed horizontal glass ring below; thus keeping its vertical diameter constant; altered to an ovoid shape. The lessened internal pressure caused the rate of air transference to fall to about one quarter of that in bubble I.

Gas Transference Through Black Bubbles in Hydrogen.

A few hydrogen bubbles blown in hydrogen were also observed. A suitable vessel for these bubbles is shown in Fig. 7.

FIG. 7.



An oxidized iron-wire ring is seen supporting a bubble, not yet completely black, within the flat-bottomed vessel, *A* (about 3 litres capacity). The filling of the vessel *A* with hydrogen is attended with considerable difficulty, and requires great care in order to obtain "optical emptiness" in the vessel. The nozzle *B* should be pushed down nearly to the bottom, while the vessel *A* is being filled with hydrogen by the tube *C* (used later as an outlet when expanding the bubble). No Tyndall cone will be

visible if the vessel is properly filled. The bubble is then blown on *B* in the usual way, and expanded and let down to rest on the wetted ring already prepared for it; or it may be left suspended from the nozzle. Both inlet and outlet tubes are protected by glycerined cotton-wool filters.

The contractions observed in hydrogen bulbs were generally more rapid than those of similar-sized air-bubbles, as shown in Tables VII, VIII, IX, where the units are the same as in the last tables.

TABLE VII.

Fifty Per Cent. Glycerine, 5 Per Cent. Soap.

	Hanging from glass nozzle.				Standing on iron-wire ring.		
Diameter	4	6	8	10	6	8	10
Internal pressure	0.45	0.30	0.23	0.18	0.30	0.23	0.18
Rate of gas transference	0.22	0.14	0.10	0.053	0.253	0.218	0.190

TABLE VIII.

Thirty-three Per Cent. Glycerine, 3 Per Cent. Soap; Hanging from Glass Nozzles.

Diameter	4	6	8	10
Internal pressure	0.45	0.30	0.23	0.18
Rate of gas transference	0.31	0.25	0.20	0.17

TABLE IX.

Approximately 1 Per Cent. Glycerine-Soap; Pale Golden Color; Hanging from Glass Nozzles.

Diameter	4	6	8
Internal pressure	0.55	0.36	0.28
Rate of gas transference	0.285	0.103	0.050

The internal pressure was not determined for every bubble; the values given above were deduced from results obtained with typical bubbles connected to an alcohol nearly horizontal displacement manometer. The instrument gave with 1 mm. of water pressure a displacement of the order of 100 mm. of the alcohol column.

A study of these results shows at once that there are obscure factors in some cases, causing notable divergencies, even when the conditions are not greatly altered. Other experiments have shown that small differences in composition have in many cases a large effect on the behavior of these thin films. Table IV (air bubbles)

shows that 4 per cent. of alcohol added to the soap solution increases the rate of gas transference through an air bubble.

The constancy in thickness of the "black stage" is undoubtedly subject to variation in different solutions. Johonnott, using a large number of small black films in a Michelson interferometer, found that there were at least two values for the thickness of the black film he measured, and that the additions of either glycerine or potassium nitrate tended to give the thicker of the two* In last year's discourse a description of five distinct grades of black was given, obtained with soap solution containing over 30 per cent. of glycerine. The film covered a thin glass frame in an exhausted glass vessel. These grades were seen to be unstable, coalescing to the deepest or thinnest black when a portion of soap solution was brought in contact with the lower part of the glass frame. It is possible that a few per cent. of alcohol, with its low viscosity and surface tension, might result in a still thinner black stage.

GAS TRANSFERENCE THROUGH BUBBLES AT PRESSURES OTHER THAN ATMOSPHERIC.

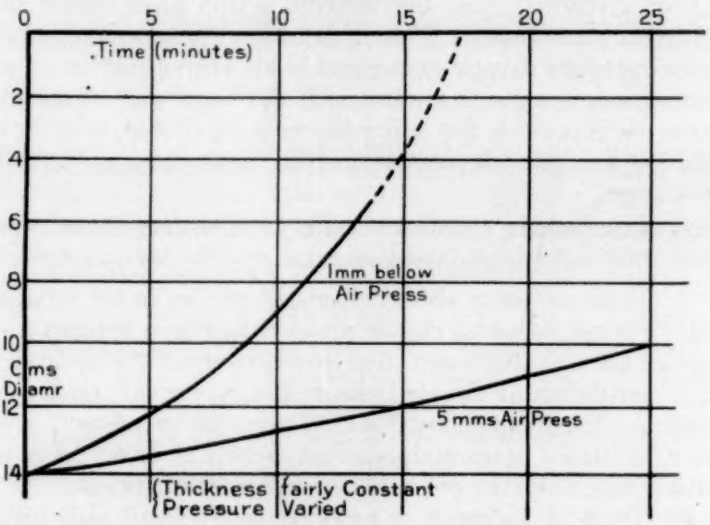
A bubble of about 10 cm. diameter, shown in an exhausted flask (Fig. 2), in which the air pressure had been reduced to the order of a fraction of a mm., was seen to contract visibly from the rapid percolation of the air from within outwards. Under such conditions the small internal excess pressure of about 0.2 mm. water, necessary to maintain a 10 cm. bubble, is a very large proportion, say about 10 per cent., of the total air pressure in the flask. There is, therefore, a proportionately small resistance to its percolation through a film sufficiently thin. As the air pressure in the vessel is increased, the time for complete contraction becomes greater, because the internal excess pressure is a relatively smaller proportion of the total opposing pressure; thus when the containing vessel is at atmospheric pressure, the 10 cm. bubble is distended by only $\frac{1}{5000}$th of this total pressure. There is, therefore, a proportionately small force urging the contained air to pass out compared with that where the vessel was under a pressure of only a fraction of a mm. The result is naturally that the complete

* "Thickness of the Black Spot in Liquid Films." By Edwin S. Johonnott, Jr., Ryerston Physical Laboratory, University of Chicago, *Phil. Mag.*, xlvii. p. 501.

contraction takes weeks instead of minutes. In the same way if a bubble be formed in a strong glass vessel charged to, say, 10 atmospheres, then even after six months, during the major part of the time being black, no sensible diminution in diameter was detected.

The measures of contraction at very low pressures were hindered by the difficulty in securing uniformity of thickness in the film. The black bubbles when obtained are extremely fugitive, as they contract so quickly. Then also the ammonium oleate solu-

FIG. 8.



Bubbles of ammonium oleate, 3 per cent. in 30 per cent. glycerine. Thinned to first green.

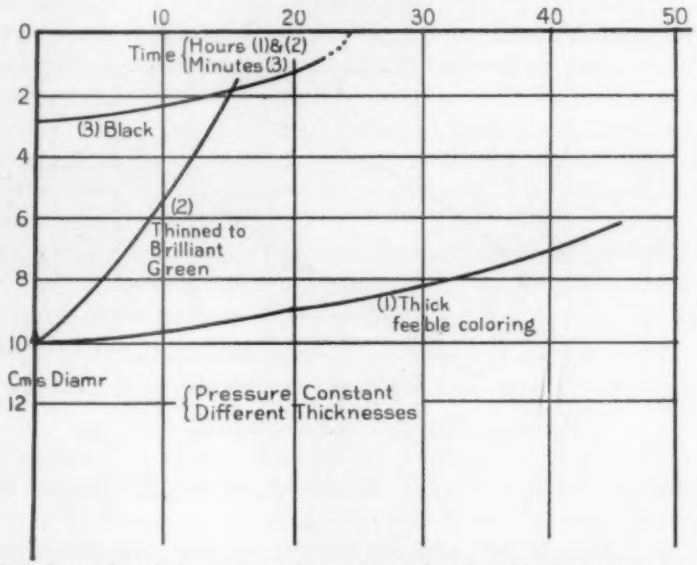
tions, which are so well adapted for obtaining black bubbles, do not remain of the same composition under low air pressures, due to the removal of the volatile easily dissociated ammonia.

The results of some of the attempts with ammonium oleates are given in Fig. 8, showing the contraction of pressures of 1 mm. and 5 mm. Hg. respectively, with approximately the same bubble thickness. The curves in Fig. 9 show the relative rates of contraction with potassium oleate at three different thicknesses of bubble, all at the same pressure of just over 1 mm. Hg.

The first of these two diagrams shows that at less than 1 mm. pressure of air in the vessel, a 14-cm. bubble composed of 3 per cent. ammonium oleate in 30 per cent. glycerine, of intense green

coloration, contracts completely in about 17 minutes; whereas if the air pressure be raised to 5 mm., the contraction of a similar bubble has only gone from 14 cm. to 11½ cm. in the same time, and to 10 cm. in 25 minutes. The second diagram shows that a bubble 10 cm. in diameter, composed of 5 per cent. potassium oleate, 50 per cent. glycerine, and almost too thick to show color, takes 47 hours to contract to 6 cm.; but when a bubble of similar size and composition is thinned to intense green, the same amount

FIG. 9.



Bubbles of potassium oleate, 5 per cent. in 50 per cent. glycerine. Air pressure over 1 mm. hg.

of contraction occurs in 9 hours; when further, the black stage is secured, the time for complete collapse from 3 cm. diameter is only 25 minutes. The green bubble, from its graph, would have taken from 2 to 3 hours for the same contraction. Such preliminary results may serve at least to point the way to a more complete inquiry.

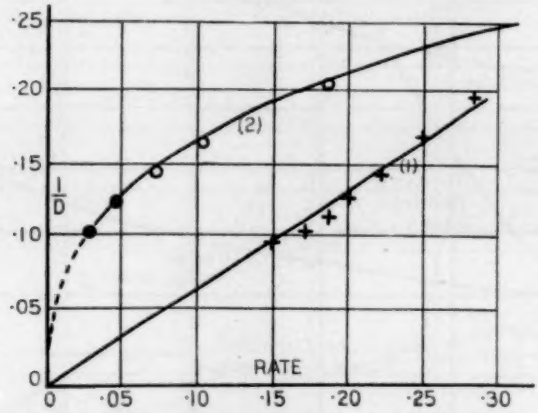
EFFECT ON THE GAS TRANSFERENCE RATE OF THE COMPOSITION OF THE SOAP SOLUTION.

The internal excess pressure, P, in a bubble of constant composition, and therefore of constant surface tension, T, enclosed in

a vessel sealed off from the atmosphere, varies inversely as the diameter, D, according to the law $P = 4T/D$.

Hence, if the rate of gas transference varies directly as the internal excess pressure, it will consequently vary inversely as the diameter. Now, in Fig. 6, taking the origin at the point where the bubble vanishes, and measuring x (time) horizontally to the right in days, and y (diameter) vertically downwards in centimetres, we found that the gas transference was measured at any time x by $-\frac{dy}{dx}$; hence $-\frac{dy}{dx} = \frac{k}{y}$ where k is a constant, the graph of $\frac{dy}{dx}$

FIG. 10.



Gas transference through bubbles. Rates plotted with reciprocals of diameters. (1) Black H bubble of constant composition. (2) Golden H bubble of increasing dilution.

to $\frac{1}{y}$ is a straight line, and the curve of contraction is the parabola $y^2 = D_0^2 - kx$, where D_0 is the initial diameter—a result usually found to be the case. The equation of the particular curve in Fig. 6 is $y^2 = 121 - \frac{121}{23}x$.

But, when a bubble partly composed of glycerine is exposed to water vapor and thereby progressively diluted, then the surface tension will increase; and the internal pressure will rise at a greater rate than would be due to diminution of diameter alone. The graph of the rates of gas transference, plotted with the reciprocals of the corresponding diameters, would no longer be a straight line. The next figure (Fig. 10) shows the graphs obtained in the case of (1) bubble of constant composition, (2) bubble of glycerine solution subjected to absorption of water vapor. In this second

case (see also Table IX) the rate of gas transference $dD/2$ (plotted as abscissæ) is increasing more quickly than the inverse of the corresponding diameters $1/D$ (plotted as ordinates)—a fact which could be explained (1) by an increase in the surface tension, with a resulting proportional increment in the internal pressure of the contracting bubble; and (2) by a more rapid percolation of hydrogen through the diluted film.

It is evident that further comparative experiments are necessary with more dilute films of constant composition before these effects can be differentiated. Preliminary attempts showed that a solution containing only 0.15 per cent. of ammonium oleate with 1.5 per cent. glycerine can give a fairly long-lived bubble (one such in hydrogen contracted completely in 28 days from 8 cm. diameter: see p. 745). But the maintenance of constant thickness is not easy, because with bubbles of such dilution even slight variations of temperature cause recurrent color changes; it is specially difficult to maintain the black stage.

No great alterations of temperature occurred in any of the above experiments, but distinct evidences of variations from this cause were noted on several occasions. The laws governing this factor have yet to be elucidated.

ALTERATION OF THICKNESS BY CONTRACTION. SILVERY DISCS. CONSTANCY OF BLACK ZONE.

A contracting bubble that remains constant in weight will, of course, become thicker as the surface diminishes. The thickness will vary inversely as the square of the diameter, provided the capillary, viscous, and gravitational forces did not come into play. For small changes, on the simple theory, the rate of logarithmic increase of thickness will be twice the rate of logarithmic diminution of diameter. This is a property of the sphere that may be expressed as follows: When S = surface, T = thickness, ρ = specific gravity of the liquid composing the bubble, then, since $S = \pi D^2$,

$$\text{Mass} = STp = \pi D^2 T \rho$$

and as the mass and composition are assumed unaltered, this gives

$$D^2T = \text{constant, or } T \text{ varies as } \frac{1}{D^2} \quad \ldots\ldots (1)$$

i.e., the thickness varies inversely as the square of the diameter, and is true for all magnitudes. Differentiating,

$$2TD.dD + D^2.dT = 0, \quad \text{or } \frac{dT}{T} = -2\frac{dD}{D} \quad \ldots\ldots (2)$$

which can be put in the form

$$d(\log T) = -2d(\log D) \quad \ldots\ldots (3)$$

Thus the rate of logarithmic increase of the thickness is twice the rate of logarithmic diminution of diameter.

In black bubbles increase of thickness can be observed if the contraction is rapidly effected by opening the closed bubble to the air, or by cautiously removing the air by suction; but the immediate effect is not to produce a colored bubble. What happens is that small silvery circular discs (see p. 721) break out over the surface of the black bubble, and these represent the aggregations of liquid resulting from the contraction, for they are much thicker than the black film through which they move. They very soon settle to the lower parts, and there slowly coalesce to a small graded colored area. This usually contracts in a short time to a much smaller zone, too thick to show color, and finally very little more is left than a small drop surrounded with a narrow silvery band on the otherwise black bubble. Large black bubbles contracting by gas percolation go too slowly for these effects to be observable, but the final result is the same: a drop of liquid slowly collects on the black bubble, and may in large bubbles grow sufficiently to fall off, after causing a progressive elliptical distortion.

Comparable behavior is shown when one or two drops of solution per minute are allowed to trickle into a black or partly black bubble. Colored streaks appear and pass downwards from places all round the supporting nozzle into which the liquid is fed; later on the streaks break up into colored discs, falling slowly by sinuous paths and with diverse motions. However, they all pass through the black portion, and after remaining for several minutes as a mass of distinct many-colored particles, form by coalescence a colored zone below round the drop. If the liquid is fed in more rapidly, the colored zone will rise to a certain extent, but, in single bubbles, a large area of black almost always remains. The feeding of the liquid may be cautiously increased almost to a stream; the bubble is then, of course, much disturbed at the boundary of the black zone, as well as elongated by the loading, and drops fall away in steady succession. The paths through the black zone may then become so thick as to be transparent threads of liquid, without any color in themselves, but causing colored rays and patches to flash outwards from their paths.

It was further observed that when a partly colored bubble

quickly altered in size, the black zone remained roughly constant in area, being independent of the extended or contracted surface. The thickness seemed to alter at the expense of the colored portion, which consequently changed in tint. A bubble is allowed to develop to blackness for about one-third of its surface, the remaining two-thirds grading from a silvery boundary at the black, through golden color to deep steel-blue. This state is reached in a few hours with a solution composed approximately of $3\frac{1}{3}$ per cent. neutral ammonium oleate in 33 per cent. glycerine, with a slight excess of ammonia. Now gradually expand the bubble by a slight reduction of the external pressure. Meanwhile, the level of the black boundary, as well as the change of diameter, are observed. The colored area is seen to change from steel-blue to blue-purple through magenta and deep amber until almost the whole of it is a full golden color as a result of the diminished thickness, which, however, is still of the order of fifteen times that of the black. During this time the black boundary has risen slightly in level; but when the area of the black zone is calculated at successive stages, the value is found to remain constant to within a few per cent. All liquid must be well drained from the hanging bubble by leaving a drainage tube in contact with the drop position, during the preliminary development to partial blackness. Two sets of observations, showing the approximate constancy of the area of the black zone, while the colored portion is varying to a large ratio, appear in Table X below.

TABLE X.

Whole Bubble.		Black Zone.	Colored Zone.	Ratio.
Diam. (cm.)	Area $(cm.)^2$	Area $(cm.)^2$	Area $(cm.)^2$	Colored: Black.
(i) 17.55	967.6	90.4	877.2	9.7
15.75	779.2	94.5	684.7	7.3
13.70	589.6	94.7	494.9	5.2
11.60	422.7	91.1	331.6	3.6
9.54	286.0	84.7	201.3	2.4
(ii) 19.1	1146	77.7	1068.3	13.9
16.1	814	76.4	737.6	9.7
13.1	539	74.5	464.5	6.2
10.1	302.5	69.1	233.4	3.4
7.1	158	35.1	122.9	3.5

Thus, from the first four observations, the actual black area of the first bubble only varied some 2 per cent. from its mean value

92.7 cm.², while the colored-to-black ratio fell from 9.7 to 3.6, or some 63 per cent.: similarly the actual black area of the second bubble varied about 5 per cent. from its mean value 74.5 cm.², while the colored area fell from nearly 14 times to 3½ times the black area—a drop of over 75 per cent.

ABSORPTION OF WATER BY BUBBLES COMPOSED OF OLEATE GLYCERINE SOLUTION.

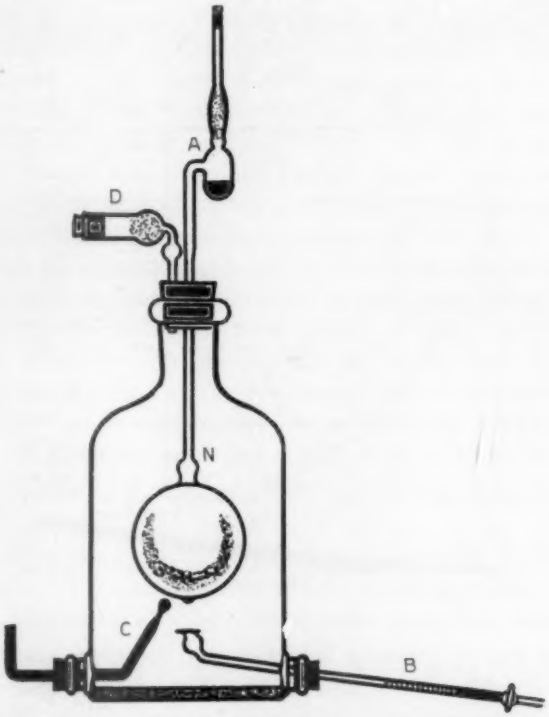
When boiled water is introduced into a vessel which holds a bubble composed partly of glycerine, water vapor is absorbed and the normal thinning of the bubble to the black stage is prevented. There is instead an increase in thickness, causing gradational changes of color: the bubble sags down from the increase in weight; successive drops accumulate and fall off, at first, maybe, two or three in a day, decreasing rapidly in number as the dilution proceeds, until when the soap-glycerine is reduced to 1 or 2 per cent. the interval between the drops grows into many weeks, and the drainage practically ceases. When very diluted the black stage is finally reached, and may remain, provided the temperature is steady; but usually much fluctuation of color takes place, the black even recurring many times.

The washings of several such bubbles were collected in a graduated tube, and periodically weighed and analyzed. In the case of a bubble of glycerine and ammonium oleate, the analysis for most purposes consisted simply in heating the liquid—in an oven at 90°–95° C.—until constant in weight. The contained glycerine and oleic acid were thus left practically in the same relative proportions as in the original bubble, water and ammonia being driven off. If necessary, the ammonia was separately estimated by Nesslerising. This is one advantage attending the use of ammonium oleate in such bubbles, as compared with the oleates of a non-volatile base like soda or potash.

The arrangements employed are shown in Fig. 11. The blowing-tube, *A*, with its nozzle, *N*, to carry the bubble, is supported in an india-rubber cork fitting the neck of a 10- to 12-litre tabulated "aspirator" vessel. *D* is a bulbed vent tube, and is packed uniformly, but not tightly, with cotton-wool moistened by glycerine. This allows any variations of atmospheric pressure to be equalized without endangering the purity of the internal atmosphere. *B* is the graduated collection tube fitted in the lower tubu-

lation; its nozzle, inside, is directly under the drops which accumulate on the bubble. Before opening the stop-cock on *B*, to draw off the accumulated liquid, the stopper in *D* is removed to allow the equalization of barometric pressure, otherwise the small quantities of liquid could not be smoothly withdrawn; alternatively, *D* may remain open. Before commencing observations any excess

FIG. 11.



liquid is removed from the bubble by drainage along the rod *C*. This is also done very effectively by a small bundle of very thin glass rods, about ¼ mm. diameter, tied together by thin aluminum wire; but the drawn-out glass rod, *C*, acts automatically when placed vertically just below the drop, for, as this grows, it descends by its own weight, and, enveloping the rounded end of the rod, drains down along the drawn-out neck, and the lightened bubble rises off the rod.

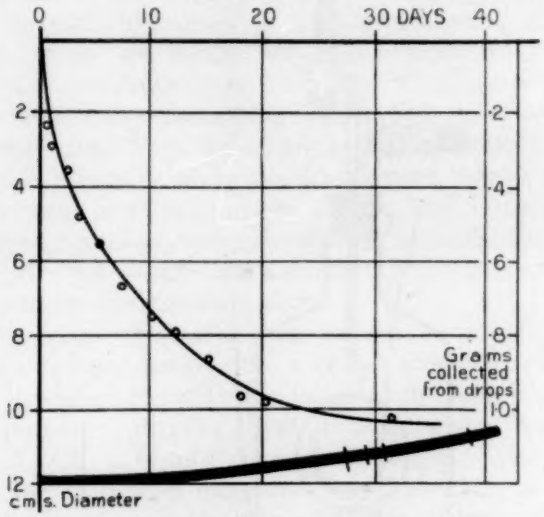
After the bubble has thus drained for several hours, the boiled

distilled water is run in. The collecting tube may be utilized for this by turning down the nozzle and tilting the vessel, or a separate inlet tube with stop-cock may be fitted.

In order to isolate the bubble from the soap solution in *A*, and prevent any distillation or intrusion of extraneous liquid, the reservoir in some experiments was removable. For this purpose a conical ground joint was made in the tube *A* above the india-rubber cork.

The contraction of the bubble is somewhat irregular, because

FIG. 12.



Air bubble over water remains colored. Contraction and condensation.

of the constantly varying thickness of the film, shown by the beautiful changes and gradings of color. In the case of an air bubble, the contraction is also relatively slow. Thus (Fig 12) one of 12 cm. diameter only diminished in forty days to 11 cm. A second one, of 21.4 cm. diameter, contracted in five months to 16.6 cm. A third one, of 15.8 cm. diameter, took a little over six months to contract to a plane film on the supporting nozzle. In wet hydrogen, however (Fig. 13), an 11-cm. bubble—under conditions of somewhat lower temperature—contracted completely in about three months; almost all this time, moreover, it was of sufficient thickness to show strong colors.

The form of the contraction curve of the hydrogen bubble is

fairly regular (considering the variations of thickness as shown by the color changes), and of similar form to that given by black bubbles of constant composition. Its collection curve, of similar type, in which the amounts collected by drainage are plotted as ordinates to the time of collection as abscissæ, is also shown in Fig. 13.

Similar contraction and collection curves are shown in Fig. 12 and Fig. 13 for air and hydrogen respectively. The left-hand vertical scales are for cms. in diameter for the contraction curves; the right-hand scales are for grams of liquid collected for the collection curves. The collection curve appears roughly as an image of the contraction curve, showing that, whereas the contraction is slow at first, increasing parabolically to the final disappearance, the condensation and drainage begins rapidly when the bubble contains concentrated glycerine, and falls off to zero as the dilution asymptotically approaches completion.

Careful measurement of such curves given by both air and hydrogen bubbles revealed them to be parabolic during the initial period before the surface became sensibly reduced by contraction. From this it follows that during this period the rate of collection is inversely as the total amount collected; just as in the contraction curves the rate of diminution of diameter is inversely as the diameter. The equation of this first portion of the drainage curve shown in the above figure for a hydrogen bubble is $y = 0.1787\sqrt{x}$, where y is in grams, and x is in days.

The approach to agreement between the observed and calculated values thus resulting is seen in the following table:

TABLE XI.

x Days.....		1	2	3	4	6	8	10	12	14
y gms.	Observed	0.18	0.26	0.305	0.36	0.45	0.52	0.57	0.62	0.66
	Calculated....	0.18	0.25	0.309	0.36	0.44	0.51	0.57	0.62	0.67

In half a day 0.1 gram of liquid had been collected; in eight days 0.5 gram was obtained; but a total of 1.0 gram was only reached on the 95th day.

The corresponding expression in terms of mgms. from each sq. cm. of the bubble surface is $y = 0.514\sqrt{x}$. The result given by

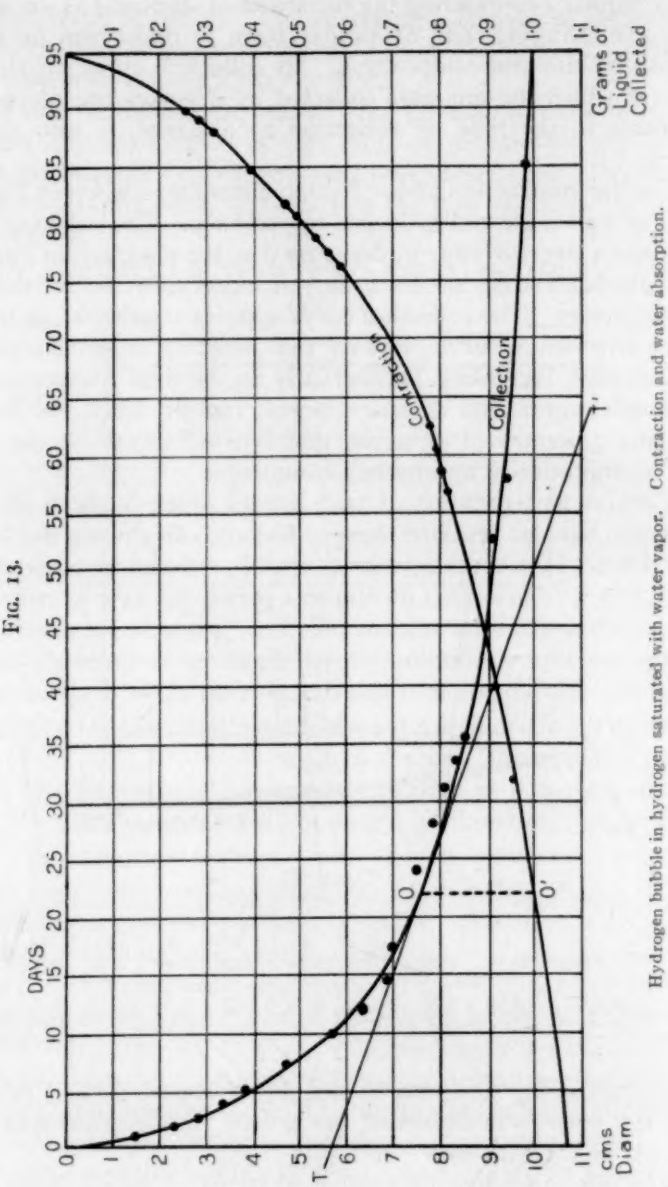


FIG. 13.

Hydrogen bubble in hydrogen saturated with water vapor. Contraction and water absorption.

the bubble under similar conditions in air instead of hydrogen was $y = 0.554\sqrt{x}$ (see Fig. 12).

The final composition of the bubble is thus relatively very little different from water. As a confirmation of this the original bubble solution (5 per cent. of ammonium oleate, in 50 per cent. glycerine) was diluted thirty-three times with carefully prepared boiled distilled water. A bubble 8 cm. diameter was then blown from this solution. It lasted until completely contracted after exactly four weeks. During most of this time it was colored amber to purple; on three or four of the warmer days nearer the end (temperature about 10° C.) it reached a semi-black stage peculiar to these very dilute bubbles. Only one drop accumulated, caused by the shrinking of the bubble. This bubble has already been referred to in connection with gas transference through bubbles of graded dilution (see p. 737).

By investigating the condensation on unit area of the bubble, instead of on the whole bubble, a simple expression can be found that is applicable to the whole of the drainage curve, instead of only to the initial period of constant surface. The rate per unit area is, of course, found by dividing the weight of total drainage by the mean surface of the bubble over the period measured. This is most readily done by drawing a succession of tangents, TT', to the collection curve (Fig. 13). The slope of these successive tangents along the curve gives the rates of collection at successive times from the whole bubble surface. The surface each time is obtained from the corresponding diameter, obtained by drawing the ordinates OO' to cut the contraction curve. By dividing the total daily drainage rate given by the slope of the tangent TT', by the corresponding surface at that time, there results the rate of condensation per unit area. The values thus accruing are set out in the first three horizontal rows of Table XII, with the corresponding day in the fourth row:

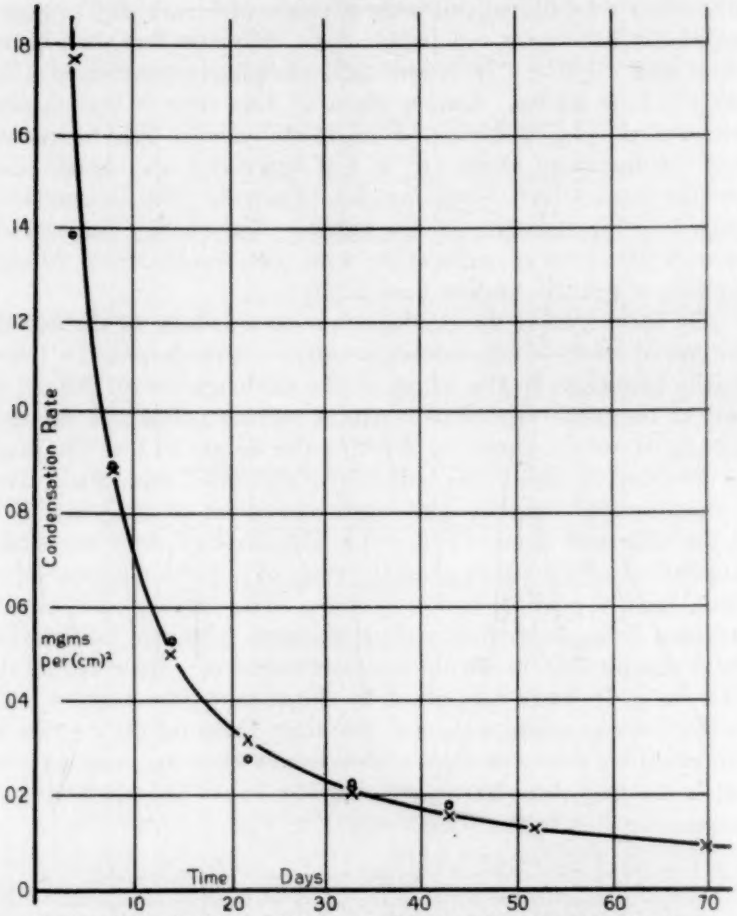
TABLE XII.

Daily rate of condensation	0.049	0.031	0.0178	0.00885	0.0064	0.0047	0.0031	0.0015
Surface	353	346.3	333.3	314.2	283.5	254.5	227.0	153.9
Rate per unit area $\times 10^4$	13.9	0.895	0.534	0.282	0.226	0.185	0.137	0.097
Day	4	8	14	22	33	43	52	70

By plotting the third and fourth rows as ordinate and abscissa, a new and more fundamental curve is obtained, which is shown in Fig. 14.

An examination of this curve shows that the alteration of the

FIG. 14.



Condensation on bubble in wet hydrogen. Rate of condensation, plotted to time.

rate of condensation *on unit area of the bubble* after the fourth day is practically hyperbolic as regards time. The expression most nearly fitting the curve is found (by plotting the results logarithmically) to be $xy = 0.705$, where x represents the time in days and

y the milligrammes of condensation on each square centimetre. Calculated points are marked " x " on the diagram, and values obtained from observations as above are marked " ⊙."

By bursting bubbles in a weighed vessel, it was found that at the mean thickness which these bubbles maintain under the given conditions (shown by their color) they have a weight of very approximately 0.1 mgm. per square cm., and are therefore 0.001 mm. thick. Hence, in the equation just given, y may also represent the weight (in milligrammes) condensed per day on each 0.1 mgm. of the bubble. The resulting values calculated for certain days are set out in the following Table XIII, together with the corresponding values obtained directly from the tangents to the original contraction curve:

TABLE XIII.

x = days.....		1	2	4	8	10	14	22	33	43	52	70
y = mgms. of condensation per mgm. of bubble	Calculated	0.705	0.352	0.176	0.090	3.071	0.050	0.032	0.021	0.016	0.014	0.010
	Observed	..	..	0.130	0.088	..	0.053	0.028	0.023	0.019	0.014	0.010

The calculated values are at first too high, but later vary slightly on either side of those directly deduced from observations (see Fig. 14).

The values in milligrammes per day, of the rate of absorption on unit area with an air bubble 15½ cm. in diameter, are given in the subjoined Table XIV. They were deduced from the weights of liquid collected in the periods named. The composition of the bubble was 50 per cent. of glycerine with 5 per cent. of ammonium oleate. This shows the rapid reduction in the daily rate of condensation occurring within a month—namely, from 0.452 mgm. at the beginning down to 0.003 mgm. at the end.

TABLE XIV.

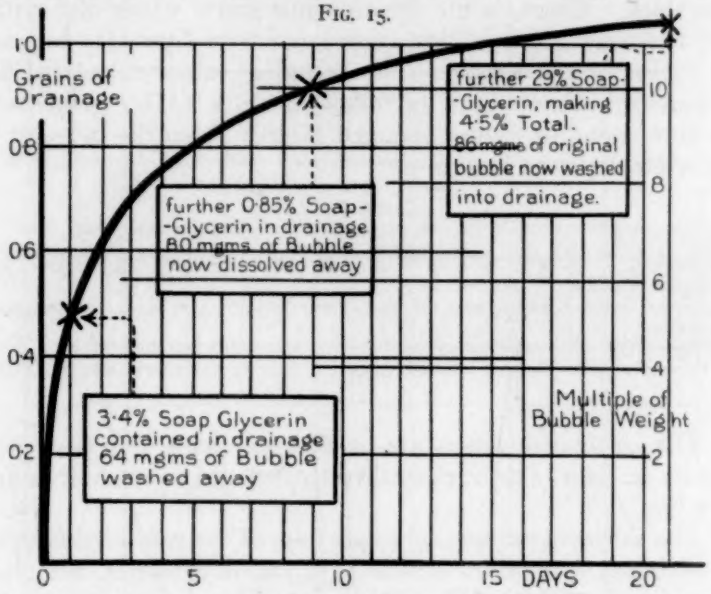
Period.	Ratio of Water-vapor Absorption.
1st day	0.452
2–9 "	0.073
10–21 "	0.014
22–34 "	0.003

ALTERING COMPOSITION OF THE BUBBLE DRAINAGE.

The variation of the composition of the liquid draining from the bubble, during the early portion of these experiments, is shown in the next two diagrams.

Fig. 15 shows the parabolic increase in the weight of the "drainage," with time; on a separate scale of ordinates, on the right-hand side, is marked the multiple of the original bubble

FIG. 15.



Altering composition of liquid collected from bubble when diluted by condensation of water. 16 cm. air bubble; 55 per cent. soap-glycerine.

weight equal to the amount of liquid collected. The three points marked are:

(1) 0.5 grm. of liquid in 1 day; being over 5 "bubble weights."
(2) 0.9 grm. of liquid in 9 days; being over 10 "bubble weights."
(3) 1.0 grm. of liquid in 21 days; being over 11 "bubble weights."

At each of these points the composition of the drainage, as well as the actual weight of the bubble which had then been washed away, were as follows:

(1) 3.4 per cent. soap-glycerine; 64 mgms. of original bubble washed away.

(2) Further 0.85 per cent. soap-glycerine; 80 mgms. of original bubble now washed away.

(3) Further 0.29 per cent. soap-glycerine; 86 mgms. of original bubble now washed away.

In Fig. 16 the ordinates on the left show the decreasing percentage of soap-glycerine in the bubble, and on the right the consequent increase in the percentage of water, as the experiment proceeded. The number of days elapsing are again marked as abscissæ. The dotted ordinate shows, for example, that the bubble on the fifth day had nearly 90 per cent. of the original soap-

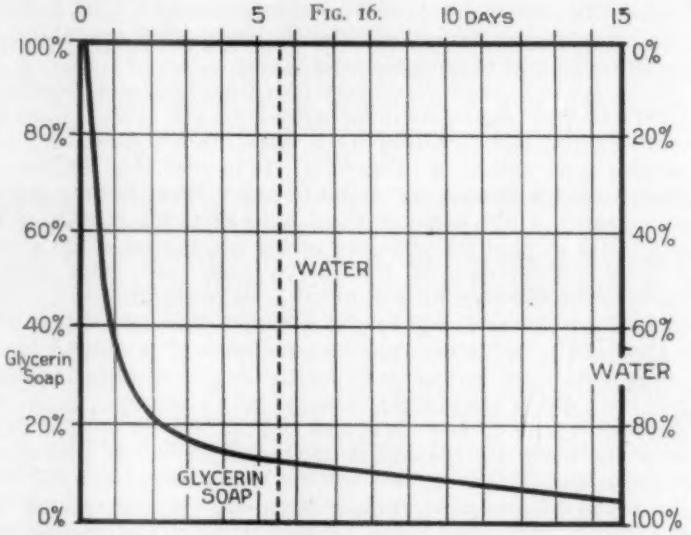


FIG. 16.

Alternating composition of bubble when diluted by condensation of water. 16 cm. air bubble.

glycerine replaced by water, and consequently only 10 per cent. of the soap-glycerine which was present in the original solution then remained; this was reduced on the fifteenth day to only about 3 per cent., but after this the rate of dilution was much less.

This intrinsic dilution curve agrees in form with that in Fig. 14, which shows the deduced rates of condensation per unit mass (0.1 mgm.) of the bubble with time. The one result follows from chemical measures of the alteration of drainage composition, while the other follows from the combined periodical observations of the weight of drainage and the contraction of the bubble.

The second part of this investigation dealing with Bubble-Complexes I hope to detail in a future discourse.

(W. J. Green, Esq., B.Sc., and J. W. Heath, Esq., F.C.S., Assistants of the Royal Institution, have aided in the course of the inquiry. [J. D.])

On the Transmission of Speech by Light. A. O. RANKINE. (*Proc. Physical Society, London,* August 15, 1919.)—Selenium changes in electrical resistance according to the light flux incident upon it. For several decades attempts have been made to transmit speech by using this fact. A beam of light is made to vary in intensity by the changes of pressure in a sound wave. This beam is received upon a selenium cell in circuit with a telephone receiver and a source of current. As long as the intensity of the light is constant so long is the current through the receiver constant. When, however, the intensity of the light changes, the resistance of the selenium changes and in consequence the current varies and the diaphragm of the receiver is made to move and to emit a sound wave.

There are two methods of making a beam of light fluctuate in intensity in accordance with the sounds of the voice. One is by controlling the light emitted by a source such as an arc lamp, by microphone action or otherwise. It is said that this method has been used with success in the German Navy over a distance of seven miles. The other method is to keep the source of light constant but to vary the intensity of the beam after it has started. The first method can, of course, be used only with artificial sources, while the second is applicable to sunlight.

A lens concentrates light upon a small spherical mirror. From this the light is reflected so as to pass through a second lens by which it is brought to a focus at which the selenium cell is placed. A grid with strips alternately transparent and opaque is put close to the first lens and between it and the mirror. A second grid of exactly the same dimensions is located close to the second lens, between it and the mirror and so that it coincides with the image of the first grid, image of opaque strip upon actual opaque strip. If the mirror is rotated about an axis parallel to the grid strips an opaque part of the second grid may receive the image of a transparent part of the first and *vice versa*. Thus no light would get through the second grid. The needle is made to turn about an axis by the lever which carries a gramophone needle. Thus, as the needle moves it tilts the mirror, which in turn shifts the image of the first grid falling on the second grid and varying quantities of light get through. The beam incident on the selenium varies the resistance, the current varies accordingly, and a sound is produced which is said to be a very good reproduction of speech. Some words, *e.g.*, "four" and "five" cause very loud sounds, while "two" and "three" produce weak sounds.

With this arrangement employing a seven-inch lens and a "pointolite" lamp the range is half a mile. More intense sources, of course, extend the range. Using the sunlight the faintest whisper was heard at a distance of one and a half miles.

The sluggishness of selenium in responding to changes in the intensity of light is a hindrance to greater efficiency. G. F. S.

THE UNITED STATES NAVAL COMMUNICATION SERVICE.*

BY

CAPTAIN S. W. BRYANT, U. S. N.

Acting Director, Naval Communication Service, Navy Department.

MR. CHAIRMAN AND GENTLEMEN: I am sure that you will regret to know that Admiral Bullard, who was to deliver this lecture, is unable to do so on account of absence on duty in France; and as he has delegated me to substitute for him, I shall do the best I can to outline the activities of the Naval Communication Service.

The practical use of radiotelegraphy for communication with vessels at sea, in the development of which the United States Navy was one of the pioneers, resulted in the erection and operation, by the Navy, of a chain of stations along the coasts of the United States for communicating with Naval and merchant vessels. For several years the development was restricted mainly to material features with the result that no progress was made toward utilizing the radio facilities that were available in a well-thought-out plan, except, of course, for tactical uses in the Atlantic Fleet where its development was fostered and great improvements were made in the fleet itself so far as related to the tactical operation of naval units. There were a number of coast stations which, individually, were excellent so far as range and operation were concerned, but we had no organization to coördinate their operation with that of the fleet.

In 1912 the so-called Naval Radio Service was established, with Captain Bullard as the first superintendent. It was apparent that the material progress made in radio was at that time much further advanced than the administrative and operating features, so that efforts were concentrated immediately on a plan for the establishment of a service of communication that would serve the needs of our fleets and merchant marine to best advantage, both in time of war and in time of peace. We had a number of stations along our coast that were individually very good, and materially

* Presented at a joint meeting of the Institute and the Philadelphia Section, American Institute of Electrical Engineers, held Wednesday, October 15, 1919.

good, and, so far as their operation was concerned, were very good; but they were not connected up in such a way as to serve the interests of the fleet to the best advantage.

The plan outlined provided for continuous communication with our fleets and among the various sub-divisions of the fleets, as well as for the coördination of all naval communication facilities so as to provide a rapid and reliable interchange of information between all naval organizations afloat and ashore.

The advisability of combining all naval communication activities—that is, telegraph, telephone, cable, etc., and radio—under one head was soon appreciated by the Navy Department, and the name of this office of the department was changed from the "Naval Radio Service" to the "Naval Communication Service," and it was placed under the Chief of Naval Operations where, logically, it belonged. It consists of three main divisions, *viz.*, Atlantic, Pacific and Philippines, and each division is subdivided into districts.

The Director of Naval Communications exercises his authority through the division heads (coast superintendents), who, in turn, direct the district superintendents. So far as is practicable, the communication districts coincide with the naval districts, and all matters of an administrative nature within a district are handled through the Commandant of the district, to whom the district communication superintendent is directly responsible for the operation and administration of naval communications within the district.

The distribution of orders or instructions and the dissemination of information from the Navy Department, or from the heads of the various naval units, is thus provided for automatically. As an illustration of how this works, it is only necessary for the Secretary of the Navy to write one message, and if he wishes the entire naval service to receive it, that is automatically taken care of by the Communication Service. Each distributing office knows to whom it should send this message and from whom to expect acknowledgment. The acknowledgments are gathered in to the coast superintendents, and eventually to the communication office in Washington, and the acknowledgement is delivered directly to the Secretary. This same procedure may be followed by the commander of any naval unit for the distribution of messages through his forces.

I want to call your attention especially to the importance that other countries have attached to communications, because we feel that the people in the United States do not appreciate the importance of a satisfactory system of American world-wide communications; certainly not so much so as is done in foreign countries. The British have two routes to the East by radio in addition to their cables running out through the Mediterranean. The Dutch have undertaken a very elaborate program. They hope to have their radio station on the Island of Curacao communicate across to the Dutch East Indies. The French have also elaborated their plans, and the Belgians have in process of erection a radio station in Belgium that will communicate direct with the United States and with their possessions in the Belgian Congo. This, of course, is in addition to the cables that are largely controlled by the various countries. England has been especially active in extending her communications, and wherever her communications go trade follows.

A very valuable experiment was carried out by the Navy Department in May, 1916, in which all the naval stations within the continental limits of the United States were connected up to a central telephone switchboard in the Navy Department, and by means of which instant telephonic communication could be had between the various naval stations and the Navy Department, and also among the stations themselves. This was made possible through the assistance of the American Telephone and Telegraph Company, and its value later on, when this country declared war against Germany, was clearly proven. It was during this test that the Commandant of the Navy Yard, Mare Island, California, talked by telephone to the commanding officer of the battleship *New Hampshire*, which was then at sea off the Virginia Capes. The Commandant's remarks came by long-distance telephone from Mare Island to Arlington, where the transmitting station was installed, and from there out to the *New Hampshire* off the Virginia Capes. The greatest value derived from this experiment, aside from the knowledge that such rapid communication by telephone was available to the Navy Department, was the fact that all of the apparatus necessary was specially marked and could be placed in operating condition on twenty-four hours' notice. As a result, the interior communications of the country, so far as naval needs were concerned, were, on the outbreak of war, in

excellent operating condition, and made the task of the Navy Department, in communicating its instructions and orders to the various naval stations, a comparatively simple one at the time of the declaration of war.

We have one cable running from the United States direct to the continent of Europe that does not touch foreign soil between the United States and the European country, and that is a direct French cable from Cape Cod to France. All other cables touch in British territory or in the Azores. In the Pacific—we have one cable to the Philippines—all American; but the British have a cable running down from Vancouver to Australia by way of the Fanning Islands. The communication situation in the Pacific is a very serious one. The British control the cables on the east coast of Brazil from Buenos Aires up north. The Americans control them on the west coast and across to Buenos Aires. Every British possession practically is connected by some means of rapid communication with the mother country.

On January 1, 1917, the Naval Communication Service operated fifty-five radio stations, distributed along the coast of the United States and its possessions. Naval vessels were equipped so that they could recieve only one message at a time. Not all of the American merchant vessels were equipped with radio apparatus, some were equipped with poorly designed radio apparatus, and none of their radio operators was proficient in the procedure of communications during war. The Navy had only 1031 radio operators in its service.

The radio technical equipment of the Navy was as good as any in general use in the United States at the time, but the demands for communication proved that the technical equipment would have to be increased and improved to conduct all of the necessary communication demanded in time of war.

At the beginning of the war the demands for quick communication increased by leaps and bounds. It was found necessary to communicate with ships in all parts of the world, while at the same time to maintain long-distance communications between the Navy Department and our outlying possessions and expeditionary forces. It was necessary to maintain continuous and rapid communication between the Navy Department and Europe, South America, Central America, West Indies, Pacific Coast, Hawaiian Islands, Guam, Tutuila, and the Far East. The most important

centres of communications were at Cavite, P. I.; Hawaiian Islands, Canal Zone, Washington, D. C., and the capitals of the Allied nations in Europe.

To meet the demands for communication, the Navy's facilities were greatly and rapidly increased, and means were provided for collecting and disseminating information to every part of our coast and to naval vessels in Europe, South America, and the Far East.

The Navy took over and operated fifty-nine commercial stations. At the same time the several privately owned stations were closed, including all the stations operated by the amateurs, which were not necessary nor desirable for use during the war. Sixty-seven land radio stations were built by the Navy during the war, all equipped with the best apparatus, thus more than doubling its radio facilities on shore.

Naval vessels were equiped with improved apparatus, so that when the armistice was signed, battleships were able to receive four messages simultaneously and transmit three. The Commander-in-Chief of the fleet could talk to the captains of vessels in the fleet; while, at the same time, the various ships of the fleet could communicate with one another. In addition, and at the same time, airplanes could communicate with their respective battleship units. None but a naval officer can appreciate the value of such a system or how much such a system facilitated the freedom of movement of the fleet.

The Navy Department equipped all American merchant vessels with modern apparatus and furnished operators for them, so that these merchant ships could receive messages at any time of the day and transmit messages at long distances in case of distress.

The Navy had to train most of its radio men because the radio amateurs in this country were soon incorporated in the army and navy. These operators were trained at Harvard. In June, 1917, there were 350 students under instruction. When the armistice was signed there were 3400 men under instruction, and operators were being graduated at the rate of about 200 a week. A total of about 7000 operators completed their training. In addition to the radio operators, it was necessary to train officers for communication duties on board the ships. At the time the armistice was signed, each ship of the Navy had a communication officer, and each merchant ship had a chief petty officer

who performed communication duties and, therefore, relieved the master of the ship from a very vexatious duty.

The year before the war there was handled approximately 125,000 dispatches from the Navy Department. These dispatches averaged about 25 words each.

From April 6, 1918, to April 6, 1919, approximately 1,000,000 dispatches, of an average of about 30 words each, were handled from the Navy Department alone. Some of these dispatches, on account of the necessity of broad-casting, were sent twice in order to insure their delivery.

As it was assumed that the use of radio apparatus by ships at sea enabled German submarines to ascertain more or less accurately the movements of such ships, communication by radio from merchant ships was discontinued except in case of emergency. Men-of-war were cautioned not to use their radio apparatus unless necessary. However, it was very necessary that information should be received on shore regarding the movements of the enemy, and that the consequent orders to ships at sea should be transmitted expeditiously. Therefore, in order to direct the movements of convoys, and to transmit information to naval vessels regarding the enemy, and to issue orders to both merchant ships and naval vessels, a comprehensive system of transmission from shore was organized with the view of making it unnecessary for ships at sea to use their radio apparatus.

All merchant vessels listened for their orders from certain designated shore stations during certain hours of the day. These messages were sent by high-power and low-power stations, depending on the distance of the ship from shore. Naval vessels intercepted messages from shore stations at all hours of the day. In order to send a message to a naval vessel at sea, it was necessary only to transmit from certain shore stations on a designated wave-length. It soon became evident that this was a very sure means of communication. Many times, fifty or sixty messages were transmitted to sea simultaneously, all destined for different classes of vessels, and they were received by ships in accordance with the plan.

The foregoing system demonstrated that ships at sea could be warned of mines and submarines, and their movements directed without the necessity of their using their own radio apparatus.

The system was automatic to such an extent that it was almost certain that a vessel could be reached at any time.

In order that errors in this system might be eliminated and in order that the Navy Department might be informed of the movements of vessels, there was established a Shipping Information Service. A confidential bulletin was published showing the movements of all United States vessels and as many foreign vessels as could be obtained. This information was collected from all the important ports of the world and the data printed in a booklet. This service grew to such an extent that the booklet now contains the names of approximately 12,000 vessels, their arrivals and departures, character of cargo, and destinations, and is of much value to shipping and business interests. It is the present plan to have the Naval Communication Service continue this publication until Congress makes other disposition for its publication.

In order to check the radio work of merchant vessels, a comprehensive system of inspection was organized, both in the United States and abroad. Every merchant vessel that came into port received a thorough inspection of its radio apparatus, and the radio operators were examined and thoroughly instructed. Any mistake indicated in the log-books was investigated and the operator instructed as to the correct method of handling such cases.

Besides inspections, the Navy maintained a comprehensive system both at home and abroad of radio repair stations. Any radio apparatus on board ship which had broken down was repaired when the ship came to port.

It soon became evident that if the commander of the United States forces in Europe was to maintain close touch with all of his forces, it would be necessary to establish and control a complete system in Europe. To this end cables were laid and land wires and radio stations constructed in France, England and in Italy. The Navy used a great many of these land wires and cables that were constructed by the Signal Corps of the Army. Close coöperation was maintained with the Allied communication services with the view of utilizing their systems whenever possible and with the view of avoiding duplication of effort.

During the war it was found necessary to maintain radio communication between the United States and our naval and military forces in Europe and in other parts of the world. In October,

1917, the Allied military and naval officials had a conference to determine the best methods of operations that were to be used in maintaining communication between the United States and Europe in case the cables were either cut by the enemy or otherwise placed out of commission.

It was decided that the United States would use the radio stations at New Brunswick, Annapolis, Tuckerton and Sayville for transmission purposes; but at this time none of these stations was in reliable communication with Europe at all times of the day and year. Therefore, it was necessary to increase the power of Tuckerton and Sayville and to place more modern apparatus in New Brunswick. The radio station at Annapolis had not been completed, and orders were given to rush the construction. There were only two transatlantic receiving stations, *viz.*, one at Chatham, Mass., and one at Belmar, N. J.

In Europe the only radio stations available for use in transoceanic communication were those at Rome, Italy; Lyons, France; and Carnarvon, Wales. Of these stations, the one at Lyons, France, was the only one able to communicate satisfactorily with the United States.

None of these stations was equipped with high-speed apparatus, and none was equipped in such a way as to avoid intentional interference from radio stations in Germany and the systems of operation and control were not such that large volumes of traffic could be handled.

At first it was decided that all messages from Europe destined to the United States would be sent during certain hours of the day from Lyons, and if possible from Rome and Carnarvon. Messages from the United States destined for Europe were to be transmitted from New Brunswick, Sayville, Tuckerton, and as soon as possible from Annapolis during the remaining hours of the day. In the beginning this system was capable of handling only a comparatively few important messages. Later, when it became evident that the Germans were making some attempt to cut cables off the coast of the United States, it was decided to erect another high-power station in France. In the meantime, improvements were being made at Lyons and Rome. The key was in the Navy Department for transmission from Sayville, Tuckerton, New Brunswick and Annapolis.

New improvements in organization and operating methods

were made both in the United States and in Europe, resulting in a centralized control of four United States high-power radio stations from the Navy Department. A receiving station was constructed at Bar Harbor, Maine, which proved to be one of the best receiving stations in the United States. The receiving stations at Chatham and Belmar were not used, as they were not necessary. The power of the radio stations at Tuckerton, Sayville and New Brunswick had been increased. At the time the armistice was signed, the United States system was capable of handling several thousand words per hour, and the whole transoceanic system was able to transmit and receive messages simultaneously without fear of intentional interference from Germany's high-power radio stations. Also, just before the armistice was signed, experiments in high-speed transmitting and photographic reception had begun. Had it been necessary, the transatlantic radio service would have been capable of handling all of the Government traffic between Europe and the United States.

When the United States entered the war it was noticed that the Central Powers were conducting a comprehensive scheme of propaganda by wireless. Counteracting this were the systems operating from France and England. The United States had no means of distributing American news throughout the world. Therefore, it was decided to use the transoceanic system of the Navy to distribute news of a reliable nature from the United States. The transatlantic stations transmitted this press news to Europe and South America. Naval vessels in South America received the press and distributed it to the local papers in those countries. The European news was distributed by Admiral Sims' headquarters and redistributed to the various capitals of Europe, including points in Russia. The Central American news was broadcasted from the Navy's high-power station in the Canal Zone, and was received in the northern part of South America and Central America and Mexico. News was distributed to the Philippines, Japan, China and Siberia, through the Navy's transpacific high-power stations. These reports were received in the Philippines, Shanghai, Vladivostok and Japan, and distributed to the local papers in those countries.

During the war it was found exceedingly difficult to locate persons in the United States who were using radio apparatus unlawfully. Also, when the German submarines began opera-

tions off the United States in June, 1918, it was found that, although the radio signals of the submarines were intercepted by naval radio stations along the coast, there were no efficient devices by which the exact location of the submarines could be ascertained from their radio signals.

It was found that enemy submarines used their radio apparatus promiscuously, and that they operated in pairs in order that they could fix the position of their prey by means of bearings. Such procedure necessitated the use of radio.

In order to counteract the foregoing situation, the Navy developed a comprehensive system of radio compasses, by means of which the bearing or direction of the enemy's signals could be obtained. Also, all signals were copied so that every time a message was sent the Navy could trace it. Shortly afterwards, it was noted that the submarines did not use their radio, and it is believed that the Navy's shore radio compass system robbed the enemy of a vital weapon, as the radio compass not only made it dangerous for the enemy to use their radio for communication purposes between one another, but also prevented them from using it for sending decoy distress messages.

Later the Secretary of the Navy "in a plan to hasten the progress of troopships" authorized the construction of fifteen additional radio compass stations, making a total of thirty-four on the Atlantic and Gulf Coasts. These radio compass stations were at harbor entrances and enabled ships at sea to enter port without consequent delays due to thick weather and fog. This was a very important item in the war as every minute counted in a ship's voyage.

After the armistice was signed, the Secretary authorized the construction of twenty-four more radio compass stations, which made a grand total of fifty-eight in the United States, and which are to be used as aids to navigation during time of peace.

The technical bureaus of the Navy Department kept pace with the operating departments in their advance in the art of radio communication and in coöperation with the radio engineers of the country accomplished some remarkable developments in radio during the war.

Efficiency in high-power transmission was increased from 30 to 90 per cent. Not only was greater efficiency arrived at with lower cost, but the power of transmission was increased. For

example, the radio station at Bordeaux, France, which is being constructed under the auspices of the Navy Department, has an input of 1000 kilowatts. Its range is estimated to be 12,000 miles. It has eight 820-foot towers.

There was an increase in speed of transmission from about 30 words a minute to 100 words a minute in actual practice, and to about 300 words a minute in prearranged tests. One of the difficulties in high-power stations was the sleet on the antennæ. Methods have been arrived at by which sleet is now prevented from accumulating on the wires of the antennæ.

The valve has been developed from a non-oscillating detector to an oscillating transmitter. It is possible to receive radio signals by the beat method and to transmit signals from the valves at comparatively long distances. The valve is used also in the transmission of speech, and is very efficient for this purpose.

Another feature of valve transmission is that it permits of very sharp tuning, which in turn permits simultaneous transmissions from a great many stations. It is believed that it will be developed in the future to such an extent that it will replace most of the existing low-power transmitters.

Another feature of the valve is that its life has increased from 5 hours to over 5000 hours, which is a very important item in the expense.

Great improvements have been made in receiving apparatus in that they are more selective, and directive receiving has increased in efficiency from 0 to 75 per cent. The old type of overhead antenna is being rapidly replaced by the use of balanced loops and underground wires, radio phase changers, and low horizontal wiring.

It is now possible to receive signals on submarines while submerged at depths of 20 feet, from shore stations, aircraft overhead, and ships afloat. This system was used to advantage in directing our submarines off our coast when they were hunting for enemy submarines.

Another improvement has been made in the radio compass, which was used at first for detecting the positions of enemy submarines, but is now developed into an aid for navigation. With properly trained personnel, the Navy is now able to give ships their positions without any large error. This will be a great boon to our merchant marine because it eliminates the delays

caused by fog and thick weather, besides making navigation generally more safe along the coast.

An interesting experiment was carried on in San Francisco from the naval station at Goat Island during a reecnt visit of the Pacific Fleet to that port. A radio telephone was installed on Goat Island, in San Francisco Harbor, and connected by land wire to the telephone company's switchboard in San Francisco. A man on board ship was thus able to talk to his friends on shore in any part of the city. Also, this friend on shore could call up the ship from his home. This means of communication with the fleet became a popular fad in San Francisco during the stay of the fleet.

The foregoing developments are just an indication of the possibilities of the use of radio communication in the future.

If the general public of the United States is to receive the best sort of service in radio communication, it will be necessary for some central controlling agency to regulate the matter. There are so many different private services that naturally wish to have radio communication that the only solution is to have it regulated by some central authoritative agency. For example, we have heard that a man in Waco, Texas, desires to build a radio station to communicate with another radio station in Boston. This service is for his private use. Another man desires to communicate between Detroit, Mich., and Los Angeles, California. This is also a private service. Another man wishes to communicate between Philadelphia and New York. This is a private service. Another man wishes to communicate between Chicago and St. Louis. This is a private service. Multiplicity of such private service will soon demonstrate to the public that the best use of radio communication is being handicapped. The man who has the circuit from Waco, Texas, to Boston may receive interference from the man who has a circuit from Detroit to Los Angeles. The man who has the service from Chicago to St. Louis may receive interference from the man who has a service from Detroit to Los Angeles. Unless there is some central regulating body which has the power to regulate the use of radio in accordance with the development of the art, it is believed that the future demand for radio communication will be limited, and in consequence the art will not progress as much as it would if it were properly fostered and regulated. The extensive use of radio in European countries

by the Allied armies and navies with the consequent experience gained has demonstrated this fact.

To illustrate how a naval communication district acts, I should like to take as an example the Third Naval District, which extends from Rhode Island to Barnegat Inlet, and in which there are eight coastal radio stations which are located as follows: Montauk, L. I.; Fire Island, L. I.; Rockaway Beach, L. I.; Sea Gate, N. Y.; Bush Terminal, N. Y.; Navy Yard, N. Y.; Mantoloking, N. J., and New London, Conn. There are also five radio compass stations located as follows: Montauk Point, L. I.; Fire Island, L. I.; Rockaway Beach, L. I.; Sandy Hook, N. J., and Mantoloking, N. J. These radio and compass stations are all controlled from one Central Control Station, located at No. 44 Whitehall Street, New York City, at which place are also the offices of the District Communication Superintendent. Direct wires from each of these stations lead into the Central Control Station, and by means of a plug-board arrangement similar in type to that used by the telephone companies, any one of these stations may be used as a transmitter by the operator on watch at the control station.

The control station is divided into a number of booths which are magnetically shielded from one another and which contain receiving apparatus of the most up-to-date type. Each booth is given a wave-length which the operator on watch must guard. There is no transmitting apparatus at this control station, all transmitting being done by means of distant control through one of the other stations mentioned above. Therefore, if the operator on watch at 600 metres receives a call and desires to answer, he promptly plugs in on a wire to any station he may decide to use and transmits via that station. He is listening all the time to what he is sending and should he hear a distress signal, he could instantly stop and give his attention to the distress call.

A chief electrician (radio) is on duty at this control station as supervisor of traffic. On his desk he has a receiver which enables him to listen in and keep check on the traffic being handled on the various wave-lengths, and, from time to time, gives orders to the various operators and stations so as to avoid interference. Such a system of supervision was found necessary in order to overcome some of the difficulties brought about by the large increase in radio traffic about the port of New York. The excellent manner in which this system functions locally about the port

of New York is another illustration of the neecssity of radio supervision by one central controlling agency.

All the stations in the Third Naval District, however, are not at all times controlled from the Central Control Station. If traffic warrants it, some outlying station, such as Montauk or Fire Island, is given orders by the supervising electrician to handle traffic independently. At such times, the outlying stations are practically acting as agents for the control station.

The great advantage, besides regulating radio traffic and cutting down the amount of interference, is that should any of the stations in the district, or the control station, hear a distress call, or any other emergency arises, the control station can immediately notify all stations to stop sending, which will leave the air clear so that the emergency may be taken care of. The ability to stop all stations in the district instantly is an absolute necessity in time of war and proved itself of much value during the time the German submarines were active along the American coast.

The radio compass stations are controlled in a manner similar to the radio transmitting stations in the Third Naval District. Each compass station in the district is connected with the Compass Control Station at No. 44 Whitehall Street, New York City (which is in the same room with the Radio Control Station) by means of direct wires. The compass stations are not equipped with transmitters, and, therefore, never work independently of the Control Station, but forward all their bearings to the supervising operator. The procedure followed by a vessel which desires her position is as follows:

The vessel calls "NAH," the call letters of Navy Radio New York, signing off with the ship's call letters, followed by the international radio abbreviation "QTE," meaning, "What is my true bearing?" or with "QTF," meaning, "What is my position?" When this signal is heard by the radio operator on watch, the compass supervisor is immediately informed and he, by means of a master key which controls all wire circuits to the compass stations simultaneously, notifies the compass stations that the ship is calling for bearings and gives the wave-length by which the ship will transmit. The radio operator in the meanwhile has acknowledged the ship's call and instructed the ship to transmit by sending dashes on whatever wave-length he may

specify. The compass supervisor, who also listens in to the radio signals, gives a signal on the wires leading to the stations when the ship commences to send dashes, or, in other words, tells all stations, "There he is now." All five stations in the district then take bearings on the ship which is transmitting, and when the supervisor calls for same, forward them to the Control Station on the wire. The supervising operator enters upon a specially prepared radio blank the bearings obtained, and before transmitting these bearings to the vessel plots them on a chart specially prepared for this purpose, noting whether a good fix was obtained. If the bearings obtained were good, he turns over the radio blank with bearings on it to one of the radio operators, who, in turn, transmits it to the vessel. If the bearings obtained are poor, as shown by plotting them on the chart, the compass supervisor informs the radio operators, who request the vessel to repeat, in order that a new set of bearings may be obtained.

The average time required to obtain the bearings and forward them to a vessel is between three and four minutes. In thick weather there are many calls for radio bearings, and the five stations in the Third Naval District are kept busy. It is always the desire of the supervising compass operator to obtain bearings from as many stations as possible, in order to note whether they all check. If bearings can be obtained from three or four stations and these bearings all intersect at one point, he is then reasonably certain that the bearings obtained are accurate.

A means of checking radio compass stations has been devised in the Third Naval District and placed in operation there. By close coöperation with the Navy Route Office, Custom House, New York, where all masters of vessels call for information regarding shipping, much data has been obtained which has proven itself useful in compiling efficient curves and records of the behavior of the radio compass stations. This system has been developed in order to be able to tell at a glance how each station behaves and what the average error is in 20-degree sectors. It has been found that in some sectors the compass may read minus, while in another sector it may read normal or plus. With such data on hand it is comparatively easy to make tests and recalibrate stations, as it is already known in what directions and by how much the station is off. Such a system is especially valuable in view of the ease with which a radio compass may be influenced

either by change in a position of the apparatus, slipping of the compass dial, or due to disturbing influences in the vicinity of the station, such as telephone wires, etc.

I just want to say a word in regard to the personnel employed at these radio compass stations. You have seen a photograph of the kind of place they have to perform their duties in, and most of the stations are in similar isolated places. In the winter time, especially, there is quite a strain on the operator, and they deserve much credit for the service they have rendered. They have to sit quietly in a small hut on some lonesome beach, listening continually for vessels on which to obtain bearings, in order that navigation may be made less dangerous and life and property at sea be safeguarded. One of the greatest drawbacks to the present radio compass installations is that so much depends upon the human element. What is badly needed, and which will undoubtedly be developed in the very near future, is an indicating instrument for use in connection with loops. When such an instrument has been devised, it will be quite simple and more accurate to obtain bearings on any radio station. At present very much depends upon the operator's acuteness of hearing and judgment, and as long as such is the case, absolutely perfect bearings cannot be guaranteed.

I want to call attention to the flexibility of the Naval Communication Service and cite as an instance the flight of the NC-4. A message was transmitted from the Navy Department to the plane during its transatlantic flight, a reply was received from the plane, and this reply was transmitted to London, Paris, San Francisco and the Canal Zone, and an acknowledgment received from those stations, all within three minutes of the time of beginning the first transmission to the plane from the Navy Department. Of course, every one was very much interested in the flight and the stations were all very keen to give the very best service, but this remarkably rapid operation was even a little better than we had anticipated.

During the Peace Conference the Naval Communication Service handled all of the radio communication for the American delegation. During the past summer, at the request of the American Relief Association, the commander of our naval forces in European waters put the Naval Communication Service personnel on land lines, handling the Relief Association messages through-

out certain countries in Europe, and they are now handling that service and will continue to handle it until peace is finally proclaimed. This involves a complete communication system in central Europe, and gives the Navy, as well as the American Relief Association, a communication system between its London headquarters and Paris, Germany, Poland, Belgium, Italy, Austria-Hungary and Turkey.

The Communication Office of the Navy Department has handled during the last year the following messages:

Sent to Europe by Navy Department	16,910
Sent to Europe by other Departments	3,645
Sent to home waters by Operations	22,870
Sent to home waters by bureaus and other departments	351,516
Received from Europe by Navy Dept. for Navy	23,034
Received from Europe by Navy Dept. for other depts.	3,893
Received from home waters to Operations	49,950
Received from home waters to bureaus and other depts.	717,313
TOTAL	794,190
Grand Total	1,189,131
Grand Total number words at 60 words per dispatch	71,347,860

The foregoing total was handled as follows:

By Costal Radio	1,621,542
By High Power Radio, Transatlantic and Continental	16,215,423
By Leased Wire, Western Union and Postal	53,500,895

The above figures are exact, except the Bureau dispatches, which are approximate and are based on the daily ratio of bureau dispatches to others during the last five months since an accurate record has been kept.

You will note that there were approximately 71,350,000 words handled by the Naval Communication Service. The high-power radio handled approximately 16,000,000. The leased wires handled approximately 53,000,000, and the coastal stations handled about 1,500,000.

During the period of demobilization a very large commercial business was done with returning transports, some of the larger transports handling fifteen hundred messages in a single month, the men wishing to send messages to their friends at home. In order to encourage this use of radio by returning troops, free

service was accorded military personnel and civilian employees of the Government in so far as the ship's sending charges were concerned. Of course, this served to increase the traffic and afforded the men a chance to communicate with their families.

During the period of the war and until April 1, 1919, practically no revenue was obtained from traffic with foreign ships. This was due to the fact that up until that time no personal messages were allowed and Allied countries, with one exception, had agreed to handle messages for Allied ships free of cost as regards shore station tolls. Pre-war charges were placed in effect for United States shore stations on April 1, 1919, and foreign ships were charged regular shore station tolls.

Owing to the congestion of the Pacific cables, the Naval Communication Service reopened the transpacific circuit to Japan and the Philippines on December 19, 1918. This service, so far as Japan was concerned, took the place of the service inaugurated by the Marconi Company about three months previous to the outbreak of the war, the Navy carrying out the agreement as to tolls between San Francisco, Pearl Harbor, and Japan. Owing to the large volume of Government business this traffic was restricted to full-rate business only.

In November, 1918, the telegraph and telephone division was in charge of a lieutenant-commander, with five officers, twelve chief petty officers and an enlisted personnel of about one hundred and thirty. The telegraph system of the Navy Department at that time included wires from Galveston, Texas, to Bar Harbor, Maine. The leased telephone wires of the Navy Department extended from Norfolk, Virginia, to Portsmouth, N. H., there being seven private telephones from the Department to New York alone. The telegraph office of the Navy Department was handling 4000 messages a day and the Navy telephone exchange was handling 18,000 telephone calls per day.

At the time of the armistice, the Daily Shipping Bulletin, which I think I referred to previously, was being printed on a hand press and about 300 copies a day were being distributed. It was very roughly made up and had not assumed any permanent form. The personnel consisted of three officers and about 100 enlisted men.

By July 1, 1919, the circulation of the Daily Shipping Bulletin had grown to nearly 2000 copies a day. It was being printed

on a power press and had assumed a standard form. Of its total circulation nearly 1400 were commercial firms, such as shipping companies, marine underwriters, ship brokers, exporters and importers, press associations, etc. The Bulletin contained the names of 12,500 ships with news of their latest movements and the record of nationality, register, tonnage and cargo. The popular demand for the Bulletin is growing daily and its success as a government activity is assured. Arrangements are under way to establish a permanent civil service personnel for the operation of the Bulletin to replace the enlisted personnel whose enlistments will expire or whose service in the reserve force will terminate.

The censorship of all cables was controlled from this office through the following branch offices:

	Personnel	
	Nov. 11, 1918	June 30, 1919
Brazil	9	0
Guam	5	0
Guantanamo Bay	3	0
Galveston	17	0
Honolulu	17	0
Cape Haitien	1	0
Key West	9	0
Lisbon	1	0
New Orleans	12	0
New York	760	78
Paris	1	0
Ponce	3	0
Panama	8	0
San Antonio	7	0
St. Croix		
Havana		
San Domingo and Puerta Plata	5	0
San Diego	1	0
San Juan	9	0
San Francisco	151	0
St. Thomas	3	0
Seattle	5	0
London	1	0
Chief Cable Censor	103	4

On April 18, 1919, by executive order, the censorship on all cables was removed from all messages except those addressed to or from German territory. This act greatly reduced the activities

of the section and all branch offices except Washington and New York were closed. On July 23, 1919, all censorship of cables was removed and this section rapidly completed its most important duties.

In closing, I would like to say that we are trying to get the people in the United States to appreciate the value of communications, and we feel that every foreign country of consequence—England, Germany, France, Italy, Belgium, and Holland—appreciate the great importance of communications and of having a system of communications over which they have control; but it seems that the people in this country have not fully realized the benefits to commerce that will naturally follow if we do have an efficient communication service with foreign countries, or such a service to those countries with which American commercial interests wish to do business.

In the Pacific, one of the most vital considerations at present is getting reliable news from the Far East into the United States, and from the United States into the Far East. The attitude in China toward Americans is one that could not be better; their feeling, as expressed to me by people who have recently been in China, is one of the deepest friendship for us, and the question of establishing communication with them and of getting reliable and recent news to and from China is one of the most important questions of the day, and I wish to emphasize the point that if there is any way of impressing upon every American the necessity for communications and the interest that the United States should take in it and in its development, and in fostering the development of high-power radio or cables, it is a patriotic duty to do so.

Manufacture of Acetic Acid from Acetylene.—In an article on organic mercury compounds F. C. WHITMORE (*Chemical Bulletin*, Chicago, vol. vi, pp. 164–165, 1919) reports that acetic acid is now made from acetylene with success on a commercial scale. Acetylene reacts with mercuric salts to form an organic compound of mercury, the exact composition of which is uncertain. Acids react with this compound to form acetaldehyde. In the commercial process acetylene is passed through a series of baths containing mercuric sulphate, sulphuric acid, and glacial acetic acid. The supply of water is so regulated that only that required for the reaction is present. Acetaldehyde is evolved in a steady stream, and is then oxidized to acetic acid by means of the oxygen of the air in the presence of a catalyst. J. S. H.

A MULTIPLE-TUBE MANOMETER.*

BY

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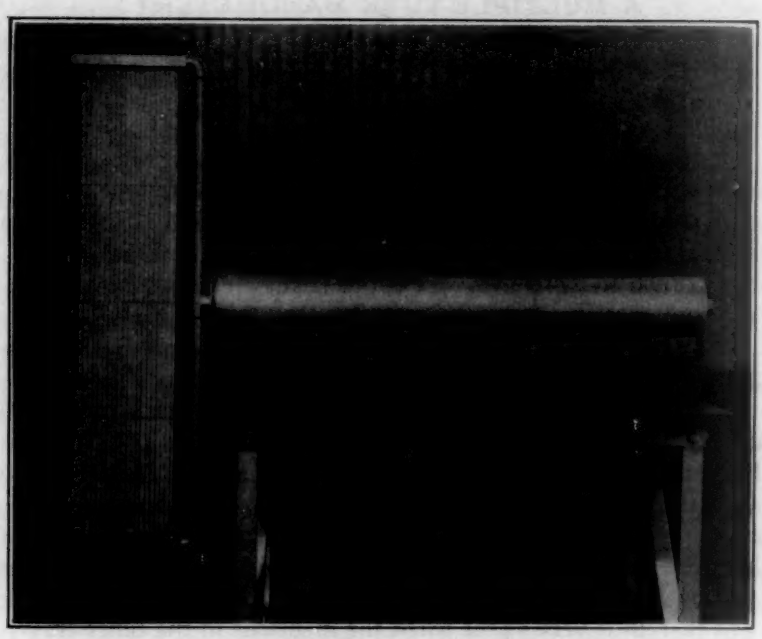
Preface.—For the measurement of pressure distribution over aerodynamic models, it is convenient to have a manometer composed of numerous tubes arranged side by side and adjustable to various sensibilities. Figs. 1 and 2 give the external appearance of such an instrument developed in the Aerodynamical Laboratory of the Bureau of Construction and Repair, early in 1917.

Description of Instrument.—A cylindrical alcohol tank rotatable in axial bearings carries at one end a tee-shaped pipe which supports a bank of twenty glass tubes mounted on a graduated metal plate. The glass tubes are sealed in sockets opening into the bottom branch of the tee, and are extended above the top branch by brass nipples for connection with rubber tubes leading to the aerodynamic surface to be studied. As the bore of the glass tubes is $^3/_{16}$ inch, the alcohol tank is made 50 inches long by 6 inches in diameter, so that the change of hydrostatic head therein is very slight when the meniscus in the tubes travels a distance of two feet, this being the probable range required in general wind tunnel use. For the measurement of large pressure differences the tubes are set vertical; for slight differences they are set on a slope of 1 in 10 by rotation of the system in its bearings; and to prevent shifting of the zero in this operation the surface of the alcohol is kept in the axis of the instrument by timely adjustment. By means of the leveling screws the axis of the tank is set horizontal, and the whole apparatus can be given a slight rotation, if need be, to correct the slope of the inclined tube-holder. The clamping of the tube system is effected by means of the spring latch shown screwed to the baseboard and engaging a slot in the flange at the near end of the tank. Three such slots are provided; one for holding the tubes vertical; one for holding them on a 1 to 5 slope; and a third for holding them on a 1 to 10 slope. The graduations on the plate back of the glass tubes, when vertical, read in inches and tenth inches of water, positive and negative.

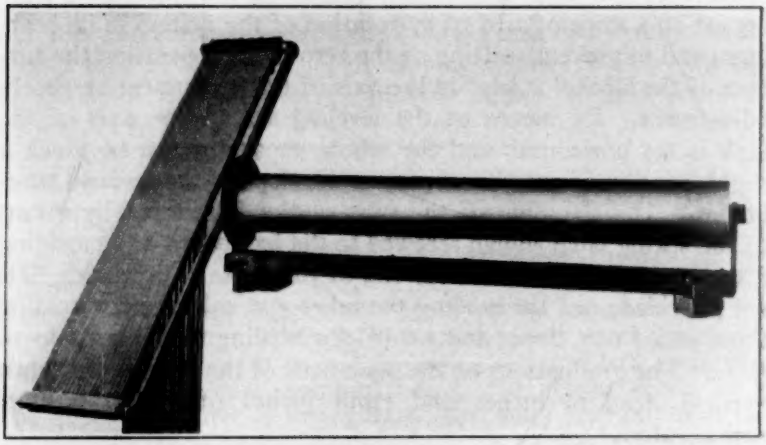
* Communicated by the Author.

FIG. 1.



Multiple tube manometer, upright.

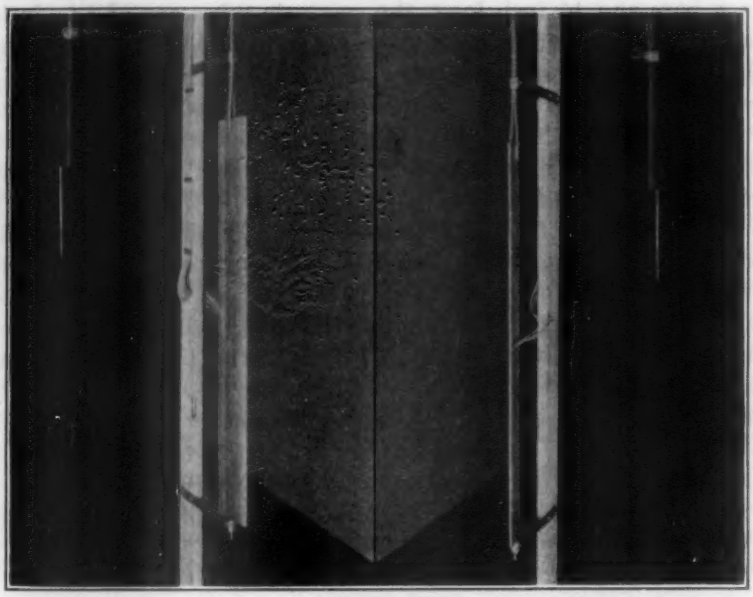
FIG. 2.



Multiple tube manometer, inclined (by rotation on a 2″ pipe running endwise through the tank and resting in end bearings).

Degree of Accuracy.—The individual tubes are calibrated with a hook gauge truly to $^1/_{1000}$ inch water head referred to the zero position of the meniscus. When so many tubes are used that the surface of the alcohol in the cistern sinks appreciably, the amount of this fall is noted on an open-ended tube and applied as a correction. This never is large. For the surface area of the fluid in the tank is ten thousand times the projected area of one

FIG. 3.



Nipple and tube connection between aerofoil and manometer.

meniscus. Hence, when one tube only is used, the error due to neglecting the fall in the tank is .01 per cent., if the tube be vertical; .05 per cent., if sloped 1 in 5; and .10 per cent., if sloped 1 in 10. If ten tubes are used at once, all under pressure or all under suction, the error is ten times as much, and may require correction, as above indicated.

Application.—Figs. 2 and 3 illustrate the manner of connecting the multiple-tube manometer to an aerofoil whose pressure distribution is to be studied at various wind speeds and incidences. From the manometer nipple ⅛-inch rubber tubing is conducted

down the back of the tube-holder; thence through the floor of the room and the ceiling of the wind tunnel; thence down a streamline strut to brass reduction couples, from the other ends of which fine spectacle tubes run to still finer nipples inserted in the aerodynamic model, to collect the pressure at a series of neighboring points. Due care is taken to locate the fine collector tubes in such manner as not to disturb the air flow over the portion of the surface under study.

In the apparatus here illustrated the brass nipples are of 0.025-inch bore and ½ inch long; the spectacle tubes are of $^1/_{32}$-inch bore and average nearly a foot long; and the whole tube system dampens the play of the alcohol columns sufficiently for convenient reading. Ten readings at a time may be taken for ten successive angles of incidence, and all completed within an hour, if the aerofoil be rotated from without, while the wind speed remains unchanged.

Except at the trailing edge of the aerofoil, each brass nipple collects the same pressure when the other nine are present as when they are absent. In an actual experiment each of the two rearmost nipples collected pressures which were false by 0.01 inch to 0.02 inch of water when the other nine were present. This error in the two rearmost pressures may entail an error of about 1 per cent. in the resultant pressue for the entire surface.

The Action of Carbonic Acid on Sulphides. (*Scientific Proceedings Royal Dublin Society*, vol. xv, p. 171, 1917.)—E. A. Letts and Florence W. Rea, in the course of a study of the chemistry of foul mud deposits, made some studies of the actions of solutions of carbonic acid on sulphides, the results of which are interesting to analytical chemists and geologists. It has long been believed that sulphates may be reduced by the action of organic matter to sulphides, and this, according to Beyerink and Van Delden, takes place under the influence of specific microbes: *Microspira desulphuricans* in fresh water, and *M. estuarii* in salt water. Letts and Rea found that a current of carbonic acid passed into a solution of sodium sulphide produces a rapid evolution of hydrogen sulphide, the whole of the sodium salt being ultimately converted into sodium acid sulphate. Calcium sulphide is decomposed to nearly fifty per cent., the soluble, so-called bicarbonate, being formed. Freshly precipitated ferrous sulphide is slowly decomposed by carbonic acid, the final result being the soluble ferrous "bicarbonate." H. L.

FACTORS OF CLIMATIC CONTROL.[1]

BY

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CHAPTER I.

GENERAL SUMMARY.

INTRODUCTION.

THE following is a discussion of the principal factors, and the effects of their possible changes, that determine what the climate —the various averages and extremes of weather—of any given place shall be; a discussion of the physics of climate and not of its geographic distribution.

Many people, relying on their memories alone, insist that our climates are now very different from what they used to be. Their fathers made similar statements about the climates of still earlier times, as did also their fathers' fathers, as their several writings show, and so on through the ages; and the bulk of this testimony is to the effect that our climates are getting worse—evidence, perhaps, that flesh has always been heir to ills. The records, however, of the past 100 years show that while there have been several slight and short-period (2 to 3 or 4 years) climatic changes during that time, that will be explained later, there have been no long-period ones. There is, though, much evidence that appreciable climatic changes of many years' duration have occurred within historic times. This evidence, which many do not accept as conclusive, is found in the growth rings of old trees; the known changes in the areas and depths of several inland seas; the records in regard to the breaking up of ice in rivers and the opening of navigation; and in a variety of other more or less significant facts.

But whatever the truth in regard to historic climates may be, nothing is more certain than that during the geologic past there have been many and important climatic changes of great duration. Innumerable fossil remains both in the Arctic and Antarctic regions tell of long ages when genial or, at least, temperate cli-

[1] Continued from p. 674, Vol. 188, November, 1919.

mates extended well among the higher latitudes, while deep scorings and ancient moraines, hundreds and even thousands of miles from the nearest existing glacier, tell quite as positively of other ages when vast ice sheets spread far into the zones we now call temperate; and this in spite of the fact (there is no good evidence to the contrary) that from the beginning of geologic records the earth has been divided into climatic zones arranged substantially as at present—warmest in equatorial regions and coldest about the poles.

It must be remembered, of course, that the previous existence of comparatively mild climates in limited high latitude regions does not prove that the average temperature of the world as a whole was then much if any higher than it is now, but only that at those places the growing seasons were long enough to permit the then indigenous vegetation to mature its seeds (a much more rapid process in high latitudes owing to the greater length of the summer days than in low), and that the temperature of the littoral waters at these same places was such as to foster the local marine life. Both conditions conceivably might have been met by a free and therefore abundant oceanic circulation; or, perhaps, locally by protection from cold currents and drifting ice. Similarly, local glaciation doubtless often was produced by local causes. But, on the other hand, such extensive glaciation as several times obtained must have required a world-wide lowering of temperature. Indeed, no escape seems possible from the conclusion that the world has experienced many a profound climatic change of both types, local and universal.

When this series of climatic changes began there is no sure means of knowing, for the records, especially those of glacial origin, grow gradually fainter and more scanty with increase of geologic age, so scanty indeed as to force the belief that the effects of many of the earlier changes may long since have been completely obliterated. But, however this may be, it is well-nigh certain that from the time of the earliest known of these changes down to the very present the series has been irregularly continuous, and the end, one might reasonably assume, is not yet. Change after change of climate in an almost endless succession, and even

additional ice ages, may still be experienced, though when they shall begin (except in the case of the small and fleeting changes to be noted below), how intense they may be, or how long they shall last, no one can form the slightest idea.

Clearly, then, a matter so fundamental as this, namely, the profound modification of those agencies that not only fashion the face of the earth, but also control its flora and govern its fauna, challenges and deserves every contribution that science can give to its complete or even partial elucidation. Hence it is that during the past fifty years, or more, numerous attempts, some of them invoking purely terrestrial and others extra-terrestrial or cosmical conditions, have been made to find a probable and at the same time an adequate physical basis for, or cause of, the known climatic changes of the distant past, and especially for those disastrous changes that brought about the extensive glaciations that prevailed during the so-called ice ages. But nearly all the older suggestions and working hypotheses as to the cause of the ice ages have been definitely and finally abandoned, either because of inconsistency with known physical laws, or abandoned because they were found inadequate to meet the conditions imposed upon them by the results of the very investigations which, in many cases, they themselves had helped to inspire.

FACTS OF CLIMATIC CHANGES.

Among the more important facts with respect to climatic changes that appear to have been established and which presumably, therefore, must be met by any theory that would account for such changes, or explain specifically the origin of ice ages, are the following:

(*a*) The number of larger climatic changes were at least several, the smaller many.

(*b*) The greater changes and doubtless many of the smaller also were simultaneous over the entire earth (there is accumulating evidence in favor of this conclusion), and in the same sense; that is, the world became colder everywhere at the same time (climatically speaking) or warmer everywhere.

(*c*) They were of unequal intensity.

(*d*) They were of irregular occurrence and of unequal duration.

(*e*) They, at least one or more, progressed with secondary variations of intensity, or with advances and retreats of the ice front.

(*f*) There often were centres of maximum intensity—certainly of ice accumulation and, doubtless, of other effects.

(*g*) There were numerous local changes, suggestive of local causes.

(*h*) They have occurred from early, probably from the earliest, geological ages down to the present, and presumably will continue irregularly to recur for many ages yet to come.

EXISTING FACTORS OF CLIMATIC CONTROL.

Before attempting to find the probable cause or causes of climatic changes it will be convenient first to consider the present factors of climatic control, since the variations of some of these undoubtedly have produced such changes, even, presumably, some if not all of those great changes that brought on maxima and minima of glaciation. It is possible, of course, that neither singly nor collectively were the factors in question largely productive of the known changes in geologic climates, but as climate to-day is subject to a complex control, all terms of which are more or less variable, it is certain that the climates of that portion of the geologic past (the only portion that will here be considered) during which the earth had an atmosphere and a hydrosphere, were also subject to a similar complex control consisting certainly of all the factors that now are effective, and probably of no others. Hence, while it is conceivable that some one dominant cause such as marked and age-long changes in the solar constant, the passage of the solar system through a vast nebula, and the like, may have produced all the great changes of geologic climates, it seems far safer to assume that climate was then controlled essentially as climate is now controlled, and, therefore, that the climatic changes of the past, whatever their nature, intensity, or duration, were due to changes in those factors of climatic control which are now operative and known to be appreciably variable.

The following list includes the principal factors of climatic control as they exist to-day:

Chief Factors of Climatic Control.

Name	Character
1. LATITUDE.	Invariable to within negligible amounts.
2. BRIGHTNESS OF MOON AND PLANETS.	Widely variable, but of no climatic significance, since they jointly produce a temperature variation of only 0.0001° C., roughly.
3. SOLAR "CONSTANT" AT A FIXED DISTANCE.	Slightly variable. There are small irregular variations of, roughly, a seven to ten day period and probably also a small variation coincident with the eleven year sun spot period. Other changes are not known, but may exist.
4. SOLAR DISTANCE.	Slightly variable, with a geologically negligible annual period due to eccentricity of the earth's orbit; and also, for the same reason, both a 100,000 year, roughly (now about 80,000 year), secular period; and a much larger pseudo period. The longer of these eccentricity changes undoubtedly are of climatic importance, but, as presently explained in the discussion of Croll's theory, there is strong evidence against the assumption that they were the chief or even an important factor in the production of glaciation. There also are slight monthly changes in the solar distance due to perturbations by the moon; and other slight changes owing to perturbations by the planets. In any case, however, the climatic effect due to perturbations is negligible—a maximum temperature change (computed) of, roughly, 0.01° C.
5. OBLIQUITY OF ECLIPTIC.	Slightly variable. According to Sir John Herschel this variation never exceeds 1° 20′ on either side of the mean; and according to Newcomb, while the limit of variation is still unknown, the amount does not exceed 2° or 3° in a million years. In either case recent geologic climates, including that of the last ice age, could not have been much influenced by this factor.
6. PERIHELION PHASE.	Variable through a period of, roughly, 21,000 years. By virtue of this variation the winter of the southern hemisphere, say, may at one time occur, as it now does, at aphelion, and therefore be long and cold; and again at perihelion, when it must be relatively short and mild. However, while this is a climatic factor which varies with the eccentricity of the earth's

Chief Factors of Climatic Control.—Continued.

Name	Character
	orbit, the period is too short to permit of its being considered as of great influence in the production of either the glacial or interglacial climates.
7. EXTENT AND COMPOSITION OF THE ATMOSPHERE.	Probably somewhat variable through geological periods, otherwise relatively fixed.
8. VULCANISM.	Irregularly variable.
9. SUN SPOTS.	Greatly variable, with an 11-year period and probably other periods also, both longer and shorter.
10. LAND ELEVATION.	Greatly variable through geological periods, otherwise relatively fixed.
11. LAND AND WATER DISTRIBUTION.	Greatly variable through geological periods, otherwise relatively fixed.
12. ATMOSPHERIC CIRCULATION.	Largely dependent upon the distribution of land and water, upon land elevation and upon oceanic circulation, and therefore, in many regions radically variable through geological periods.
13. OCEAN CIRCULATION.	Greatly variable through geological periods, otherwise relatively fixed.
14. SURFACE COVERING.	Greatly variable, in many places, from season to season; and also irregularly so from age to age.

Since these are the factors that now control climate, it seems probable, as already stated, that even those profound climatic changes with which the geologist is concerned were also caused by variations in one or more of these same factors. Indeed, certain of these factors—vulcanism, land elevation, and oceanic circulation—are known to have varied greatly during the several geologic periods, while the extent and composition of the atmosphere are suspected also to have changed. It will be well, therefore, to consider what effects such variations probably could have—in some cases surely have had—on our climates. This will constitute the first step in the problem of geologic climates. The next step must be taken by the geologist himself, for he must say whether the climatic changes possible through the supposed causes would be sufficient to account for the observed results, and especially whether the known climatic changes and the known variations in

the factors here considered occurred at such times and places as to permit of the assumption that they were actually related in the sense of cause and effect.

These several factors will be considered in the same order as above listed.

1. Since the wandering of the pole is limited to only a few metres, it is obvious that the resulting changes in the latitude produce no appreciable climatic effects.

2. The brightness of the moon, and also that of each of the several planets, is known in terms of that of the sun. On the assumption that the heat they supply is in proportion to their light it appears that at most their variations in phase and distance can alter the temperature of the surface of the earth by no more than 0.0001° C., an amount that obviously is wholly negligible.

CHAPTER II.

PRINCIPAL ICE-AGE THEORIES.

FACTORS 3, 4, 5, 6, 7.

IT would be easy to catalogue perhaps a score of more or less rational hypotheses in regard to the origin of the ice ages, the subject under which the greater climatic changes generally are discussed, and doubtless even a larger number that are quite too absurd ever to have received serious consideration, and to point out in each case the known and the suspected elements of weakness. But this would only be a repetition of what, in part at least, has often been done before and, therefore, could serve no good purpose.

As already stated, only a few of these hypotheses still survive, nor do all of even these few really merit the following they have. Indeed, the only ones which still claim a large number of adherents are, respectively:

3. (*a*) *The Solar Variation Theory.*—This is based on the assumption that the solar radiation (the only solar influence that by any known process can affect terrestrial temperatures and terrestrial climates) has waxed and waned, either cyclically or irregularly, through considerable ranges and over long intervals of time.

This theory is seductively attractive—it looks so simple, so

sufficient, and so safe from attack. There are, however, two criticisms of it that should be mentioned: (1) A change of the solar constant obviously alters all surface temperatures by a roughly constant percentage. Hence a decrease of the heat from the sun would, in general, cause a decrease of the interzonal temperature gradients; and this in turn a less vigorous atmospheric circulation, and a less copious rain or snowfall—exactly the reverse of the condition, namely, abundant precipitation, most favorable to extensive glaciation. (2) If the solar variation theory is true it follows, as will be shown later, that great solar changes and extensive mountain building must usually, if not always, have been coepochal—a seemingly complete *reductio ad absurdum*.

4, 5, 6. (*b*) *Croll's Eccentricity Theory.*[2]—To make this theory clear, it is necessary to recall two important facts in regard to the earth's movement about the sun: (1) That the orbital position of the earth at any season, that of midsummer, say, progressively changes at such rate as to describe a complete circuit in about 21,000 years. This necessarily produces a cyclic change of the same period in the length, temperature and contrast of the seasons, and also in the contrast between the climates of the two hemispheres, northern and southern. Thus, when aphelion is attained near midsummer of either hemisphere as it now is for the northern, that part of the earth enjoys comparatively long, temperate summers, and short, mild winters; while the opposite hemisphere, the southern at present, is exposed to short hot summers, and long, cold winters. Hence, on such occasions, the climatic contrast between the two hemispheres is at a maximum, provided, of course, that their ratios of land to water areas and other factors are the same. After about 10,500 years another maximum contrast occurs, but with the climates of the two hemispheres interchanged, and so on indefinitely. (2) That the eccentricity of the earth's orbit, never greater than 0.07, and at rare intervals dropping to nearly or even quite zero, undergoes irregular but always slow and long cyclic changes. In addition to a change usually, though not always, relatively small whose average period is roughly 100,000 years (now about 80,000), the eccentricity has also a far more irregular and generally much larger change whose average period, if a thing so irregular may be said to have

[2] *Phil. Mag.*, **28**, p. 121, 1864, and elsewhere.

a period, is three or four times as great. That is, as a rule, the eccentricity of the earth's orbit is continuously large, within the limit 0.07, or continuously small, for a period of 200,000 years, more or less; but in each case unequally so, because of the shorter period and more regular changes.

The first of these phenomena, the continuous change of the perihelion phase, varies, as explained, the relative lengths and intensities of the summers and winters of the northern and southern hemispheres; while the second, or the change of eccentricity of the earth's orbit, varies the magnitudes of these contrasts.

Now Croll's theory of the ice ages assumes that when the earth's orbit is very eccentric, or when the earth's maximum solar distance differs largely from its minimum solar distance, ice will accumulate to a great extent over that half of the globe which has its winter during aphelion.

For some time this theory was very generally accepted, and it seems still to have many adherents, despite the destructive criticisms of Newcomb[3] and Culverwell.[4]

The chief objections to Croll's theory are:

1. That the assumption that midwinter and midsummer temperatures are directly proportional to the sun's heat at these times is not at all in accord with observed facts.

2. That each ice-age (within a glacial epoch, when eccentricity is large) would be limited to a fraction of the secular perihelion period, 21,000 years, which, according to most geologists, is too short a time.

3. That the successive ice ages would have occurred alternately in the northern and southern hemispheres instead of, as is generally believed to have been the case, in both hemispheres simultaneously.

4. That during the past 3,000,000 years there would have been fully 100 extensive glacial advances and retreats in each hemisphere (eccentricity having been rather large through much the greater portion of this time), a deduction unsupported by confirmatory geological evidence.

5. That the last extensive ice sheet in either hemisphere must have retracted roughly to its present limits some 80,000 years ago (eccentricity having become small about that time and remained

[3] *Amer. Jr. Sci.*, 11, p. 263, 1876; *Phil. Mag.*, 17, p. 142, 1884.

[4] *Phil. Mag.*, 38, p. 541, 1894.

small ever since) instead of less than 9000 as Gerald de Geer [5] has well-nigh conclusively demonstrated.

As W. B. Wright [6] puts it: "An almost fatal objection to Croll's famous theory is the date it assigns to the end of the last Ice Age, which it places at some 80,000 years back. If, as De Geer seems to have clearly established, the ice-margin retreated north past Stockholm only about 9000 years ago, this practically excludes any possibility of a connection between glaciation and changes in the eccentricity of the earth's orbit."

That changes in the maximum and minimum distances of the earth from the sun have affected our climates and that they will continue to affect them seem too obvious to admit of doubt, but that such changes ever were, or ever will be, of sufficient magnitude to be the sole, or even the chief, cause of an ice-age appears to be flatly contradicted both by rigid deductions from the laws of physics and meteorology and by close observations of geological records.

7. (*c*) *The Carbon Dioxide Theory.*—This theory, advocated by Tyndall,[7] Arrhenius,[8] Chamberlain [9] and others, is based on the selective absorption of carbon dioxide for radiation of different wave lengths, and on its assumed variation in amount.

It is true that carbon dioxide is more absorptive of terrestrial than of solar radiations, and that it therefore produces a greenhouse or blanketing effect, and it is also probably true that its amount in the atmosphere has varied through appreciable ranges, as a result of volcanic and other additions on the one hand, and of oceanic absorption and chemical combination on the other. But it is not possible to say exactly how great an effect a given change in the amount of carbon dioxide in the atmosphere would have on the temperature of the earth. However, by bringing a number of known facts to bear on the subject it seems feasible to determine its approximate value. Thus the experiments of Schlaefer [10] show that, at atmospheric pressure, a column of carbon dioxide 50 centimetres long is ample for maximum absorption, since one of this length absorbs quite as completely as does

[5] *Geolog. Congress*, Stockholm, 1910.
[6] *The Quarternary Ice Age*, p. 451, Macmillan and Co., 1914.
[7] *Phil. Mag.*, **22**, p. 277, 1861.
[8] *Phil. Mag.*, **41**, p. 237, 1896.
[9] *Jr. Geol.*, **7**, p. 545, 1899.
[10] *Ann. der Phys.*, vol. xvi, p. 93, 1905.

a column 200 centimetres long at the same density. Also the experiments of Angström,[11] and those of E. v. Bahr,[12] show that the absorption of radiation by carbon dioxide or other gas increases with increase of pressure, and, what is of great importance, that both qualitatively and quantitatively this increase of absorption is exactly the same whether the given higher pressure be obtained by compression of the pure gas to a column of shorter length, or, leaving the column unchanged, by the simple addition of an inert gas.

According to these experiments, if a given column or quantity of carbon dioxide at a pressure of 50 mm. absorbs 20 per cent. of the incident selective radiation, then, at 100 mm. it will absorb 25 per cent., at 200 mm. 30 per cent., at 400 mm. 35 per cent., and at 800 mm. about 38.5 per cent.

Now, the amount of carbon dioxide in the atmosphere is equivalent to a column of the pure gas, at ordinary room temperature and atmospheric pressure, of roughly 250 centimetres in length. Hence, as a little calculation proves, using the coefficients of absorption at different pressures given by the experiments of Angström and E. v. Bahr, just described, the carbon dioxide now in the atmosphere must, under its present vertical distribution, absorb radiation very approximately as would a column 475 centimetres long of the pure gas at the barometric pressure of 400 millimetres. But Schlaefer's experiments above referred to show that such a column would be just as effective an absorber as a cylinder two or three times this length, and, on the other hand, no more effective than a column one-half or one-fourth as long; in each case the absorption would be complete in the selective regions of the gas in question.

Hence, finally, doubling or halving the amount of carbon dioxide now in the atmosphere, since this would make but little difference in the pressure, would not appreciably affect the total amount of radiation actually absorbed by it, whether of terrestrial or of solar origin, though it would affect the vertical distribution or location of the absorption.

Again, as explained by Abbot and Fowle,[13] the water vapor

[11] *Arkiv för Matematik, Astron. och Fysik*, vol. iv, No. 30, 1908.

[12] *Ann. der Phys.*, vol. xxix, p. 780, 1909.

[13] *Annals of the Astrophysical Observatory*, Smithsonian Institution, vol. ii, p. 172, 1908.

always present in the atmosphere, because of its high coefficients of absorption in substantially the same regions where carbon dioxide is effective, leaves but little radiation for the latter to take up. Hence, for this reason, as well as for the one given above, either doubling or halving the present amount of carbon dioxide could alter but little the total amount of radiation actually absorbed by the atmosphere, and, therefore, seemingly, could not appreciably change the average temperature of the earth, or be at all effective in the production of marked climatic changes.

Nevertheless, in spite of the above objections, there appears to be at least one way (variation in absorption at levels above the water vapor) by which a change, especially if a decrease, in the amount of carbon dioxide in the atmosphere might affect temperatures at the surface of the earth. Hence, the above arguments do not perhaps fully warrant the idea that no such change was ever an appreciable factor in the production of an ice age.

Further consideration of this particular point will be taken up later, after the discussion of certain other questions essential to a clear understanding of the subject.

These three theories, then, of the origin of the ice ages, namely: The solar variation theory, the eccentricity theory, and the carbon dioxide theory, are the only ones that at present appear to have many adherents, and even these few seem more likely to lose than to gain in number and ardency of defenders. The first is strong only as, and to the extent that, other theories are disproved or shown to be improbable; the second has failed utterly under searching criticism; while the third has been sadly impaired.

CHAPTER III.

8. VULCANISM: THEORY.

(The mathematical portions of this chapter, provided their conclusions are accepted, may be omitted in reading without serious loss of continuity.)

GASEOUS CONTRIBUTION TO THE ATMOSPHERE.

ALTHOUGH a variety of gases, vapors and fumes are given off by active volcanoes, probably only one of them, carbon dioxide, is of sufficient volume and of such nature as to produce any effect on climate. Indeed, besides carbon dioxide, the only atmospheric constituents that are especially effective in modifying

the average temperature of the earth are water vapor and, probably, ozone. The former of these, or water vapor, except as locally modified by temperature and topography, including location and extent of land and sea, presumably has varied but little in amount since the formation of the earliest oceans, while a practically continuous series of animal fossils from beyond the earliest paleozoic age to the present is abundant proof of an equally continuous supply of free oxygen. Hence, in an effort roughly to determine what climatic changes might have been caused by variations in the atmosphere, whether produced by vulcanism or otherwise, it would appear that only the amount of carbon dioxide need be considered.

But this has been discussed above, to some extent, and will be taken up again in its proper order. Suffice it to anticipate here the general conclusion that while variations in the amounts of carbon dioxide in the atmosphere may have somewhat modified our climates, it probably never was the controlling or even an important factor in the production of any one of the great climatic changes of the past, nor can be of any great climatic change the future possibly may bring.

CHANGE IN SURFACE COVERING.

The effect of volcanic ejecta, whether in the nature of ash, or lava flow, is to convert the region so covered into a temporary desert, even where rain may be abundant, and, therefore, to subject it to an increased range of temperature extremes, and at the same time, if in a previously vegetated region, slightly to increase its average temperature, owing to decrease of evaporation. However, it seems highly probable that the areas so deprived of vegetation were never at any one time sufficiently large to produce marked effects upon the climate of the world as a whole, nor indeed anywhere except over themselves and within their own immediate neighborhoods. Hence, in considering universal climatic changes, it seems safe to neglect this special effect of volcanic activity.

DUST IN THE UPPER ATMOSPHERE.

It was suggested a number of years ago by the cousins P. and F. Sarasin [14] that the low temperature essential to the glaciation

[14] *Verhandlungen der Naturforschenden Gesellschaft in Basel*, vol. xiii, p. 603, 1901.

of ice ages was caused by the absorption of solar radiation by high volcanic dust-clouds. But the idea that dust of this nature, when scattered through the atmosphere, may lower the temperature of the surface of the earth was already old, having been advanced at a much earlier date, in fact, long before even the existence of ice ages had been suspected, much less attempts made to find their cause. Thus, in May, 1784, Benjamin Franklin (and he may not have been the first) wrote as follows:

> During several of the summer months of the year 1783, when the effects of the sun's rays to heat the earth in these northern regions should have been the greatest, there existed a constant fog over all Europe, and great part of North America. This fog was of a permanent nature; it was dry, and the rays of the sun seemed to have little effect toward dissipating it, as they easily do a moist fog arising from the water. They were indeed rendered so faint in passing through it that, when collected in the focus of a burning-glass, they would scarce kindle brown paper. Of course, their summer effect in heating the earth was exceedingly diminished.
>
> Hence the surface was early frozen.
>
> Hence the first snows remained on it unmelted, and received continual additions.
>
> Hence perhaps the winter of 1783-4 was more severe than any that happened for many years.
>
> The cause of this universal fog is not yet ascertained. Whether it was adventitious to this earth, and merely a smoke proceeding from the consumption by fire of some of those great burning balls or globes which we happen to meet with in our course round the sun, and which are sometimes seen to kindle and be destroyed in passing our atmosphere, and whose smoke might be attracted and retained by our earth; or whether it was the vast quantity of smoke, long continuing to issue during the summer from Hecla, in Iceland, and that other volcano which arose out of the sea near that island, which smoke might be spread by various winds over the northern part of the world, is yet uncertain.
>
> It seems, however, worthy the inquiry, whether other hard winters, recorded in history, were preceded by similar permanent and widely-extended summer fogs. Because, if found to be so, men might from such fogs conjecture the probability of a succeeding hard winter, and of the damage to be expected by the breaking up of frozen rivers in the spring; and take such measures as are possible and practicable to secure themselves and effects from the mischiefs that attend the last.[18]

The idea, then, that volcanic dust may be an important factor in the production of climatic changes is not new, though by what physical process it could produce this result apparently has not

[18] See Sparks's "Life of Benjamin Franklin," vol. vi, 455–457 (cited in *Proceedings of the Amer. Phil. Soc.*, vol. xlv, p. 127, 1906.)

formerly been explained, nor has the idea previously been specifically supported by a long series of direct observations. This is not to be taken as a criticism of the above-mentioned pioneer paper by the Sarasin cousins, for indeed the arguments, now easy, necessary to show that it must be a factor, were at that time impossible, because the observations upon which these arguments largely are based had not then been made. In fact, the absorption of radiation by volcanic dust, by which they supposed the earth's temperature to be lowered, can now be shown to be, of itself alone, not only insufficient, but even productive, in all probability, of the opposite effect—of a warming instead of a cooling of the earth's surface.

To make this point clear: Consider a thin shell of dust about the earth and let I be the average intensity of the normal component of solar radiation on it, and I_e the intensity of the radiation reaching the earth. Further, let a be the average coefficient of absorption of the dust shell for solar radiation, a coefficient independent, presumably, of intensity, and b its coefficient of absorption for terrestrial radiation, also independent of intensity. Obviously, in the case of equilibrium, all the energy absorbed by the dust is radiated away; half of it, very approximately, to the earth and half of it to space. Hence, starting with I as the intensity of the solar radiation normally incident per unit area and unit time, upon the dust layer, we have,

$$I_e = I \left\{ 1 + k\,(b - a) \right\} \quad \text{- - - - - - - - - - - (A.)}$$

in which

$$k = \tfrac{1}{2} \left\{ 1 + \frac{b}{2} + \left(\frac{b}{2}\right)^2 + \cdots\cdots + \left(\frac{b}{2}\right)^{\infty} \right\}.$$

Now b is positive, and, therefore, k is also positive. Hence

$$I \left\{ 1 + k\,(b - a) \right\} \begin{matrix} > \\ = \\ < \end{matrix} I, \text{ according as } b \begin{matrix} > \\ = \\ < \end{matrix} a.$$

The conclusion, therefore, is: *The total amount of radiation reaching the earth is increased, unchanged, or decreased owing to absorption by the surrounding dust layer according as the dust's coefficient of absorption of terrestrial radiation is greater than, equal to, or less than its coefficient of absorption of solar radiation.*

Actually nearly all, both of the incoming and of the outgoing radiation, is oblique, but as equal portions of each pass through

equal thickness of the shell it follows that the conclusion reached for normal radiation applies also for the oblique radiation.

While this general conclusion is self-evident, and, therefore, might have been stated without the use of symbols, nevertheless equation (A), to be used later on, will be found convenient in attempts to obtain quantitative values.

Now in the case of many, if not all, rocky materials, such as make up the particles of volcanic dust, the coefficient of absorption is much greater for terrestrial radiation than for solar radiation,[16] or, in terms of the above symbols, in the case of volcanic dust, b is greater than a. Hence, so far as mere *absorption* of radiation is concerned, the only action mentioned by the cousins Sarasin, a veil of volcanic dust, in all probability, would slightly increase and not, as they supposed, decrease the average temperature of the earth.

But, then, absorption is not the only effect of a dust veil on radiation; *reflection* and *scattering* both are important and must be fully considered.

These actions, however, reflection and scattering, depend fundamentally upon the ratio of the linear dimensions of the particles concerned to the wave length of the incident radiation, and, therefore, before undertaking to discuss them in this connection, it will be essential to determine the approximate size of the individual grains of floating volcanic dust, and also the average wave lengths in the regions of the respective maximum intensities of solar and terrestrial radiation. It will be desirable, also to consider whether or not, and, if so, how, dust of any kind can remain long suspended in the atmosphere. And this point, involving the structure of the atmosphere, will be examined first, since, obviously, the longer the dust can float the more important, climatically, it may have been in the past and in the future may again become.

Physical Structure of the Atmosphere.—The atmosphere is divisible into the stratosphere and the troposphere; or the isothermal region and the convective region; or, in other words, that region, in middle latitudes at and beyond about 11 kilometres above sea level, where, because of freedom from vertical convection, ordinary clouds never form, and that other, or turbulent,

[16] Coblentz, Publications of Carnegie Institution of Washington, Nos. 65 and 97.

stormy region below this level, which is frequently swept by clouds and washed by snow and rain. The physical reason for or cause of the existence of the isothermal region is well known (see Chapter III, Part I) and is such that it is certain that ever since the earth was warmed by solar radiation, as at present, rather than by internal heat, the temperature of its atmosphere beyond a certain level, whatever its composition, must have varied but little, as it now varies but little, with change of altitude, and therefore that this region must then have been free, as it now is free, from clouds and condensation. Obviously, then, this peculiar physical structure of the atmosphere is of great importance in determining the duration of dust suspension for, clearly, any volcanic or other dust, that by whatever process is gotten into and distributed through the isothermal region where there are no clouds or other condensation to wash it out, must drift about until gravity, overcoming the viscosity of the atmosphere, by slow degrees shall have pulled it down to the region of clouds and storms, where it becomes moisture laden and quickly brought to the earth. How long such process must take depends, of course, upon a number of things, among which the size of the particles is vitally important.

Size of Volcanic Dust Particles.—For two or three years after the eruption of Krakatoa, in 1883, also after the eruption of Mont Pelé and Santâ Maria, in 1902, and again after the eruption of Katmai, in 1912, a sort of reddish-brown corona was often, under favorable conditions, observed around the sun. It was from 10 to 12 degrees wide, and had, to the outer edge, an angular radius of from 22 to 23 degrees. This phenomenon, known as Bishop's ring, clearly was a result of diffraction of sunlight by the particles of volcanic dust in the upper atmosphere, and therefore it furnished a satisfactory means for determining the approximate size of the particles themselves. The subject has been rather fully discussed by Pernter,[17] who finds the diameter of the particles, assuming them spherical, to be approximately 185×10^{-6} cm., or 1.85 microns. The equation used has the form

$$r = \frac{m}{\pi} \frac{\lambda}{\sin \theta}$$

in which r is the radius of the dust particle, λ the wave length of

[17] *Met. Zeit.*, 6, p. 401, 1889.

the diffracted light (here taken as 571×10^{-7} cm., or 0.571 micron), θ the angular radius of the ring, and m a numerical term which for the outer edge of the ring, and successive minima of brightness, has the approximate values,

$$\frac{\pi}{2}(n + 0.22)$$

in which $n = 1, 2, 3, \ldots$, respectively.

Now, since the width and angular dimensions of Bishop's ring, as seen at different times and different places, have varied but little, the above value, 1.85 microns, may provisionally be assumed to be the average diameter of those particles of volcanic dust that remain long suspended in the atmosphere.

Time of Fall.—The steady or terminal velocity of a sphere falling in a fluid, assuming no slip between fluid and sphere, is given by Stokes's [18] equation,

$$V = \frac{2}{9} g r^2 \left(\frac{\sigma - \rho}{\mu}\right)$$

in which V is the velocity of the fall, g the acceleration of gravity, r the radius of the sphere, σ the density of the sphere, ρ the density of the fluid, and μ its viscosity.

However, there always is slip, so that the actual velocity of fall is, according to Cunningham,[19]

$$V = \frac{2}{9} g r^2 \left(\frac{\sigma - \rho}{\mu}\right)\left(1 + A\frac{l}{r}\right)$$

in which l is the free path of the gas molecules, A a constant, and the other symbols as above explained.

Obviously, l, other things being equal, is inversely proportional to the gas density, or pressure, if temperature is constant, and directly proportional to the absolute temperature if the pressure is constant. Hence,

$$V = \frac{2}{9} g r^2 \left(\frac{\sigma - \rho}{\mu}\right)\left(1 + \frac{B}{rp}\right) \quad \ldots\ldots\ldots\ldots \quad (1)$$

in which B is a constant for any given temperature, p the gas pressure, or, if preferred, barometric height.

Now, a series of valuable experiments by McKeehan [20] has

[18] *Math. and Phys. Papers*, vol. iii, p. 59.
[19] *Proc. Roy. Soc.*, **83 A**, p. 357, 1910.
[20] *Phys. Rev.*, 33, p. 153, 1911.

shown that for 21° C., and when p is the pressure in terms of millimetres of mercury,

$$B = .0075 \pm 3.$$

The value of μ, for dry air, is also closely known from the work of a number of experimenters, all of whom obtained substantially the same results. From a careful review of the whole subject, Millikan [21] finds that at 23° C.,

$$\mu = 1824 \times 10^{-7}, \left(\text{more recently } 18226 \times 10^{-8} \right),$$

and that, for the temperature, t, Centigrade,

$$\mu_t = \frac{150.38\, T^{\frac{3}{2}}}{T + 124} \times 10^{-7}, \text{ approximately,}$$

where $T = 273.11 + t$.

It is easy, therefore, to compute, by the aid of equation (1), the velocity of fall of volcanic dust, assuming gravity to be the only driving force. There is, of course, radiation pressure, both toward and from the earth, as well as slight convective and other disturbances, but presumably gravitation exerts the controlling influence.

The following table of approximate velocities and times of fall for volcanic dust was computed by substituting in equation (1) the given numerical values, namely:

$g = 981 \frac{\text{cm.}}{\text{sec.}}$
$r = .000092$ cm.
$\sigma = 2.3$ approximate density of Krakatoa dust.
$\rho = 0$, being negligible relative to σ.
$\mu = 1416 \times 10^{-7}$, appropriate to −55° C., roughly the temperature of the isothermal region in middle latitudes.
$B = .0056$, appropriate to −55° C.
$p =$ millimetres barometric pressure.

According to this table, it appears that spherical grains of sand of the size assumed, 1.85 microns in diameter, would require about one year to fall from only that elevation already reached by sounding balloons, 35.08 kilometres,[22] down to the under surface of the isothermal region, at the height of 11 kilometres.

[21] *Ann. der Phys.*, 41, p. 759, 1913.
[22] *L'Astronomie*, 27, p. 329, 1913.

Velocity and Time of Fall

Height in kilometres	Barometric pressure	Centimetres per second	Seconds per centimetre
40	1.84	1.0215	0.979
30	8.63	0.2414	4.143
20	40.99	0.0745	13.427
15	89.66	0.0503	19.874
11*	168.00	0.0408	24.492
0	760.00	0.0258†	38.760†

* Isothermal level of middle latitudes.
† Temperature 21° C.

As a matter of fact, volcanic dust, at least much of it, consists of thin-shelled bubbles or fine fragments of bubbles, and, therefore, must settle much slower than solid spheres, the kind above assumed. Indeed, the finest dust from Krakatoa, which reached a great altitude, probably not less than 40 nor more than 80 kilometres, was from two and a half to three years in reaching the earth, or, presumably, as above explained, the upper cloud levels.

At any rate, volcanic dust is so fine, and the upper atmosphere above 11 kilometres so free from moisture and vertical convection, that once such dust is thrown into this region, as it obviously was by the explosions of Skaptar Jökull and Asamayama in 1783, Babuyan in 1831, Krakatoa in 1883, Santâ Maria and Pelé in 1902, Katmai in 1912, and many others, it must require, as a rule, because of its slow descent, from one to three years to get back to the earth. And this clearly has always been the case since the earth first assumed substantially its present condition, or had a cool crust and a gaseous envelope.

Obviously, then, it is only necessary to determine the present action of such dust on incoming solar and outgoing terrestrial radiation in order to reach a logical deduction as to what its effect on climate must have been in the past if, through extensive volcanic activity, it ever more or less continuously filled the upper atmosphere for a long or even considerable term of years, as may have happened several times during the geologic ages. And the same conclusion in regard to the possible effect of dust on the climates of the past clearly applies with equal force to the climates of the future.

Action of Dust on Solar Radiation.—Since solar radiation at the point of maximum intensity has a wave-length less than

5×10^{-5} cm.,[23] or half a micron, and since fully three-fourths of the total solar energy belongs to spectral regions whose wave-lengths are less than 10^{-4} cm., or one micron, it follows that the cubes of solar wave-lengths must, on the whole, be regarded as small in comparison with the volume of a volcanic dust particle, the diameter of which, as above explained, is nearly 2 microns. Hence, in discussing the action of volcanic dust on incoming solar radiation, we can, with more or less justification, assume the particles to be opaque through reflection or otherwise, and, therefore, use Rayleigh's[24] arguments as applied to a similar case.

Let r be the radius of the particle, n the number of particles per cubic centimetre, and a the projected joint area of these particles. Then, for random and sparsely scattered particles,

$$a = n\pi r^2$$

Hence, on dividing a plane parallel to the wave-front into Fresnel zones, it is seen that for each centimetre traversed the amplitude of the radiation is reduced in the ratio of 1 to $1 - n\pi r^2$. Therefore, if A is the initial amplitude, and A_x the amplitude after passing through x centimetres of the uniformly dusty region, assuming $n\pi r^2$ to be only a small fraction of a square centimetre,

$$A_x = A\,(1-n\pi r^2)^x = Ae^{-n\pi r^2 x}$$

Further, if I is the initial and I_x the final intensity, then

$$I_x = Ie^{-2n\pi r^2 x}$$

Hence, in the case of volcanic dust, where, as already explained, $r = 92 \times 10^{-6}$ centimetre,

$$A_x = Ae^{-n\pi x\,(92)^2\,10^{-12}}$$

and

$$I_x = Ie^{-2n\pi x\,(92)^2\,10^{-12}}$$

Presumably, the particles of dust are not absolutely opaque and, therefore, I_x probably is a little larger than the value here given, though even so this value is at least a first approximation.

[23] Abbot and Fowle, *Annals Astrophys. Obsy.*, Smithsonian Inst., vol. ii, p. 104, 1908.

[24] *Phil. Mag.*, 47, p. 375, 1899.

Action of Dust on Terrestrial Radiation.—Terrestrial radiation, at the point of maximum intensity, has a wave-length of roughly, 12×10^{-4} centimetres, and, therefore, the wave-lengths of nearly all outgoing radiation are large in comparison with the diameters of those volcanic dust particles that remain long suspended in the atmosphere. Hence, while such particles abundantly *reflect* solar radiation, as is obvious from the whiteness of the sky when filled by them, they can only *scatter* radiation from the earth, according to the laws first formulated by Rayleigh,[25] whose papers must be consulted by those who would fully understand the equations which here will be assumed and not derived.

Let E be the intensity of terrestrial radiation as it enters the dusty shell, or as it enters the isothermal region, and E_y its intensity after it has penetrated this region, supposed uniformly dusty, a distance y centimetres; then, remembering that the dust particles are supposed to be spherical, according to Rayleigh,

$$E_y = Ee^{-hy}$$

where

$$h = 24\pi^3 n \frac{(K' - K)^2}{(K' + 2K)^2} \frac{T^2}{\lambda^4},$$

in which n is the number of particles per cubic centimetre, K the dielectric constant of the medium, K' the dielectric constant of the material of the particles, T the volume of a single particle, and λ the wave-length of the radiation concerned.

But $K = 1$, and, since the dust seems generally to be a kind of glass, it may not be far wrong to assume that $K' = 7$. Hence, with these values,

$$h = 11\pi^3 n \frac{T^2}{\lambda^4}, \text{ nearly.}$$

Relative Action of Dust on Solar and Terrestrial Radiation.—To determine whether such a dust layer as the one under discussion will increase or decrease earth temperatures it is necessary to compare its action on short wave-length solar radiation with its action on long wave-length radiation from the earth.

In the case of solar radiation, as explained,

$$I_x = Ie^{-2n\pi x (92)^2 10^{-12}}$$

[25] *Loc. cit.*

Clearly, then, the intensity of the solar radiation is reduced in the ratio of 1 to e, or

$$I_x : I = 1 : e$$

when $x = \frac{10^{12}}{2n\pi (92)^2}$ centimetres $= \frac{188}{n}$ kilometres, approximately.

On the other hand, in the case of terrestrial radiation, where

$$E_y = Ee^{-11\pi^3 n \frac{T^2}{\lambda^4} y},$$

the intensity is reduced in the ratio of $1 : e$, or

$$E_y : E = 1 : e,$$

when

$$y = \frac{\lambda^4}{11\pi^3 n T^2} \text{ centimetres,}$$

in which

$$T = \tfrac{4}{3}\pi (92)^3 10^{-18}$$

and

$$\lambda = 12 \times 10^{-4}, \text{ the region of maximum intensity.}$$

Hence,

$$y = \frac{5700}{n} \text{ kilometres, approximately.}$$

Therefore, finally,

$$y : x = 30 : 1, \text{ roughly,}$$

or the shell of volcanic dust, the particles all being the size given, is some thirty-fold more effective in shutting solar radiation out than it is in keeping terrestrial radiation in. In other words, the veil of dust produces an inverse greenhouse effect, and hence, if the dust veil were indefinitely maintained, the ultimate equilibrium temperature of the earth would be lower than it is when no such veil exists.

The ratio 30 to 1 in favor of terrestrial radiation in its ability to penetrate the dusty atmosphere may at first seem quite too large, but it should be remembered that the dust particles in question are to terrestrial radiation in general as air molecules are to solar radiation, in the sense that in both cases but little more than mere scattering takes place. Now it is obvious that the dust particles are many fold more effective in intercepting solar

radiation, which they appear to do chiefly by reflection, than is an equal mass of air molecules which simply scatter it; and hence it may well be that the above theoretically determined ratio, 30 to 1, is no larger than the ratio that actually exists, or, at any rate, that it is of the correct order.

It must be distinctly understood that certain of the assumptions upon which the foregoing is based—uniformity of size, complete opacity and sphericity of the dust particles, for instance—are only approximately correct, but they are the best that at present can be made, and doubtless give at least the order of magnitude of the effects, which, indeed, for the present purpose, is quite sufficient.

It may be well, in this connection, to call attention to the fact that the excessively fine dust particles, or particles whose diameters are half, or less, the wave-length of solar radiation (region of maximum intensity), and which, therefore, remain longest in suspension, shut out solar radiation many fold more effectively than they hold back terrestrial radiation. This is because both radiations, solar and terrestrial, are simply scattered by such small particles, and scattered in proportion to the inverse fourth power of the wave-length. Indeed, since the ratio of solar wave-length to terrestrial wave-length (region of maximum intensity in both cases) is, roughly, 1 to 25, and the ratio of their fourth powers as 1 to 39×10^{-4}, about, it follows that the interception of outgoing radiation by the very finest and therefore most persistent dust is wholly negligible in comparison with its interception of incoming solar radiation.

Number of Dust Particles.—The intensity of the solar radiation, I_x, after it has passed through x centimetres of the dust layer of the atmosphere, is given, as previously explained by the equation,

$$I_x = Ie^{-2n\pi x(92)^2 \times 10^{-12}}$$

But, according to numerous observations made during the summer and fall of 1912, when the solar radiation had passed entirely through the dust layer at such an angle that it met, roughly, twice as many dust particles as it would have met had it come in normally, or from the zenith, it was reduced by about 20 per cent. That is to say, under these conditions

$$I_x = 0.8\, I.$$

Hence

$$10 = 8e^{2n\kappa\pi}(92)^2 10^{-12}$$

Let $n\kappa = 2N$. the total number of particles passed in a cylinder of one square centimetre cross section. Then

$$10 = 8e^{4N\pi}(92)^2 10^{-12}$$

Hence the number of particles in a vertical cylinder of one square centimetre cross section is given, roughly, by the equation

$$N = 34 \times 10^4.$$

Temperature Correction Due to Dust Radiation.—With the number and size of the dust particles known it is easy to determine at least an upper limit to the effect of the direct radiation of the particles themselves on the temperature of the earth.

The temperature of the dust particles, obviously, is very nearly that of the upper atmosphere in which they float, that is, approximately −55° C., or 218° C. absolute. Also, as previously explained, the quantity of radiation from the atmosphere below the isothermal region is substantially that which would be given off by a full radiator at 256° C. absolute.

Now assume the dust particles to be concentrated side by side on a common plane, and, further, assume them to be full radiators —conditions that would raise their effect to the theoretical upper limit. Let E be the intensity or quantity per square centimetre of the outgoing planetary radiation, and D the intensity of the incoming dust radiation. Then

$$E : D = (256)^4 : a(218)^4,$$

in which a is the projected area of all the particles in a vertical cylinder of one square centimetre cross section.

But

$$a = 34\pi\ 10^4(92)^2 10^{-12} = 9 \times 10^{-3}.$$

Hence

$$E = 211\ D.$$

Now, when the radiation D is absorbed by the lower atmosphere, it follows that its temperature will be so increased that, when equilibrium is reached, the intensity of its new radiation will be to that of its old as 212 is to 211. Hence ΔT, the ef-

fective temperature increase of the lower atmosphere, is given by the equation

$$\frac{(256 + \Delta T)^4}{(256)^4} = \frac{212}{211},$$

from which

$$\Delta T = 0°.3\ C.$$

But, as stated above, the dust particles, presumably, are not full radiators, and, therefore, probably one-fifth of a degree C. is as great an increase in temperature as may reasonably be expected from this source. But this *increase,* 0.2° C., is small in comparison with the *decrease,* 6° C. to 7° C., caused by the interception of solar radiation, already explained. *Hence it appears reasonably certain that the sum total of all the temperature effects produced by volcanic dust in the upper atmosphere, equal in amount to that put there by the explosion of Katmai, must be, if long continued, a lowering of the surface temperature by several degrees C.*

Total Quantity of Dust.—Let $nx = 2N$, the total number of particles passed in a cylinder of one square centimetre cross section. Then, as explained above,

$$10 = 8e^4 N\pi (92)^2 \times 10^{-13}.$$

Hence

$$N = 34 \times 10^4$$

roughly = number of particles in a vertical cylinder of one square centimetre cross section.

If A is the entire area of the earth in square centimetres, then the total number of dust particles, assuming the dustiness everywhere as just found, is

$$NA = 1734 \times 10^{21}.$$

But the radius of each particle is 92×10^{-6} cm., and its volume, assuming it spherical, 33×10^{-13} cubic centimetre. Hence the total volume of the dust, assuming the particles spherical, is equal, roughly, to a cube 179 metres, or about 587 feet, on the side, an amount that certainly is not prohibitively large.

As just stated, the total quantity of dust sufficient, as explained, to cut down the intensity of the direct solar radiation by 20 per cent., and therefore, if indefinitely continued, capable, presumably,

of producing an ice age, is astonishingly small—only the 174th part of a cubic kilometre, or the 727th part of a cubic mile, even assuming that the particles are spherical. Since, however, in large measure, the particles are more or less flat, it follows that the actual total mass of the dust necessary and sufficient to reduce the intensity of direct solar radiation by 20 per cent. probably is not more than the 1500th part of a cubic mile, or the 350th part of a cubic kilometre.

Hence, even this small amount of solid material distributed once a year, or even once in two years, through the upper atmosphere, would be more than sufficient to maintain continuously, or nearly so, the low temperature requisite to the production of an ice age; nor would it make any great difference where the volcanoes productive of the dust might be situated, provided only that it was driven high into the isothermal region or stratosphere, since, from whatever point of introduction, the winds of the upper atmosphere would soon spread it more or less evenly over the entire earth.

A little calculation shows, too, that this quantity of dust yearly, during a period of 100,000 years, would produce a layer over the earth only about half a millimetre, or one-fiftieth of an inch, thick, and therefore one could hardly expect to find any marked accumulation of it, even if it had filled the atmosphere for much longer periods.

Whether periods of explosive volcanic activity—and in this case, since the locality of the volcano is a matter of small importance, the whole earth must be considered—occurred at such times as to synchronize with the ice ages and with other epochs of great climatic change is, of course, a problem for the geologist to solve. However, this much appears well-nigh certain: Since the beginning of reliable records, say 160 years ago, the average temperature of the earth has been perceptibly lower, possibly as much as 0.5° C., than it would have been if during all this time there had been no volcanic explosions violent enough to put dust into the isothermal region of the atmosphere. Similarly, on the other hand, if, during this period, violent volcanic explosions had been three or four times more numerous than they actually were, the average temperatures probably would have been 1° C. to 2° C. lower, or low enough, if long continued, to depress the snow line roughly 300 metres, and thus to begin a moderate ice age.

Effect of Dust on the Interzonal Gradient.—If I is the initial intensity of radiation of a given wave-length and aI its intensity after passing a unit distance through a homogeneous absorbing or scattering medium, then its remaining intensity, after traveling n units distance through this medium, will be $I\ a^n$. But n, in the case of solar radiation passing through the atmosphere, is proportional to the secant of the zenith distance of the sun; and from this in turn it is evident that, in general, variations of dust in the upper atmosphere must change the temperatures of the high latitude regions more than these within the Tropics. Hence, an increase of such dust would steepen the interzonal temperature gradients, strengthen the winds, and make heavier the rain and snowfall, a condition favorable to extensive glaciation. Of course, the increased circulation would, in turn, more or less reduce the new temperature difference, but, nevertheless, a portion, at least, of the increase clearly would remain, and with it the corresponding increases of wind and rain.

CHAPTER IV.

VULCANISM: OBSERVATIONAL.

IT will be interesting and profitable now to consider the supplementary portion of the theory of the relation of vulcanism to climate. That is, to consider the observational evidence, pyrheliometric or other kind, bearing on the effect of volcanic dust on solar radiation, and thus obtain some idea of those absolute values essential to even a rough determination of the climatic consequence of volcanic dust in the high atmosphere.

Pyrheliometric Records.—Direct measurement of solar radiation by means of the pyrheliometer, an instrument that measures the total heat of sunshine, shows marked fluctuations from year to year in the intensity of this radiation as received at the surface of the earth. This subject has been carefully studied by Dr. H. H. Kimball,[26] of the United States Weather Bureau, who prepared the accompanying table, graphically represented by Fig. 1. Since the yearly values are given in terms of the average value for the entire period, it is obvious that percentages of this average do not represent the full effect of the disturbing causes, of which volcanic dust certainly is the chief.

[26] *M. W. R.*, 46, p. 355, 1918.

Year	Number of stations	Radiation
1883	1	103
1884	1	92
1885	1	89
1886	1	96
1887	1	105
1888	1	101
1889	1	100
1890	1	96
1891	1	95
1892	2	99
1893	2	104
1894	2	102
1895	2	103
1896	3	103
1897	3	103
1898	3	104
1899	3	103
1900	3	101
1901	3	102
1902	3	99
1903	3	88
1904	3	96
1905	3	100
1906	3	102
1907	5	98
1908	5	99
1909	5	102
1910	5	102
1911	5	103
1912	5	92
1913	5	93

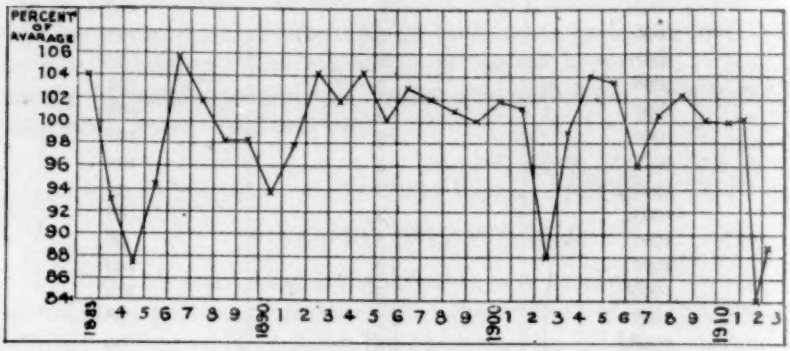
The above table of intensities was computed from observational data obtained at the following stations:

Montpellier, France, monthly means (noon values).. 1883–1900
Pavlovsk, Russia, monthly maxima..... 1892–1913
Lausanne, Switzerland, monthly means (noon values)..1896–1904
Warsaw, Russia, monthly maxima 1901–1913
Washington, D. C., and Mount Weather, Va., monthly means for air mass 2.0..... 1905–1913
Simla, India, monthly means (noon values)..... 1906–1913
Paris, France, monthly maxima 1907–1913

The marked decrease in the pyrheliometric readings for 1884, 1885, and 1886 doubtless were largely, if not almost wholly, due

to the eruption of Krakatoa in the summer of 1883; the decreased values of 1888 to 1892, inclusive, occurred during a period of exceptional volcanic activity, but were probably due essentially to the violent eruptions of Bandaisan (1888), Bogoslof (1890), and Awoe, on Great Sangir (1892); the low values of 1903 to the eruptions of Santâ Maria (1902), Pelé (1902) and Colima (1903); and the low values of 1912–1913, to the explosion, June 6, 1912, of Katmai. The slight depression in the curve corresponding to the year 1907, during which no violent eruptions were reported (this does not exclude the possibility of such

FIG. 1.



Annual average, pyrheliometric values.

occurrence in remote and unfrequented regions), according to Dr. Kimball, probably was caused by local haze at Washington, D. C., where his observations were made, and elsewhere, and this supposition is partially supported by the fact that his values for the year were not uniformly low, and by the further fact, inferred from a publication by Gorczynski,[27] that during that year the solar radiation was but little below normal at Warsaw, Russia.

There is, then, abundant pyrheliometric evidence that volcanic dust in the upper atmosphere actually does produce that decrease in direct solar radiation that theory indicates it should, and, as the theory is well founded and the observations were carefully taken, this mutual confirmation may be regarded as conclusive both of the existence of volcanic dust in the upper atmosphere

[27] *C. R.*, 157, p. 84, 1913.

(isothermal region) and of its efficiency in intercepting direct radiation from the sun.

It should be remembered, however, in this connection, that the intensity of the solar radiation at the surface of the earth depends not only upon the dustiness of the earth's atmosphere, but also upon the dustiness, and, of course, the temperature, of the solar atmosphere.

Obviously, dust in the sun's envelope must more or less shut in solar radiation just as, and in the same manner that, dust in the earth's envelope shuts it out. Hence it follows that when this dust is greatest, other things being equal, the output of solar energy will be least, and when the dust is least, other things being equal, the output of energy will be greatest. Not only may the intensity of the emitted radiation vary because of changes in the transparency of the solar atmosphere, but also because of any variations in the temperature of the effective solar surface, which, it would seem, might well be hottest when most agitated, or at the times of spot maxima, and coolest when most quiescent, or at the times of spot minima.

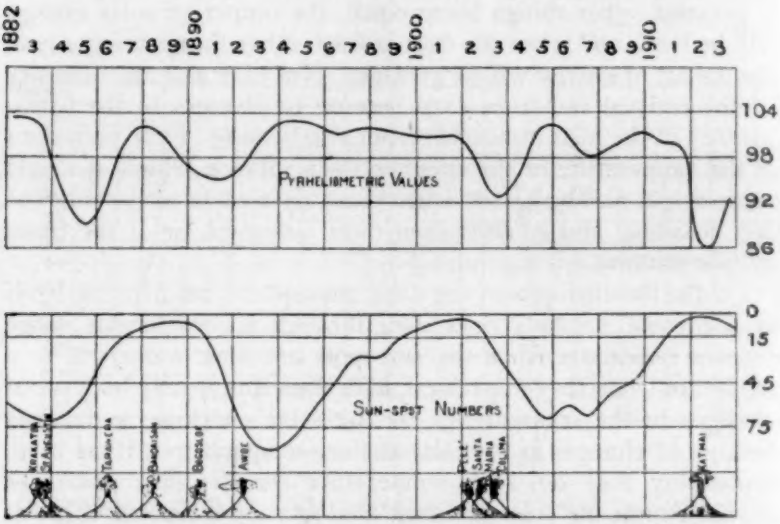
Now, the dustiness of the solar atmosphere, manifesting itself as a corona, certainly does vary through a considerable range from a maximum when the sun-spots are most numerous to a minimum when they are fewest, and, therefore, partly because of changes in the transparency of the solar envelope, and partly because of changes in the solar surface temperatures, if, as in all probability they do, such temperature changes take place, we should expect the solar constant also to vary from one value at the time of spot maximum to another at the time of spot minimum, and to vary as determined by the controlling factor, dust or temperature.

If the above reasoning is correct, it follows that pyrheliometric readings are functions of, among other things, both the solar atmosphere and our own terrestrial atmosphere; and as the former is altered chiefly by sun-spots or at least varies with their production and existence, and the latter by volcanic explosions, a means is at hand for comparing the relative importance of the two radiation screens.

Fig. 2 shows one such comparison. The upper curve gives smoothed annual average pyrheliometric readings (not solar constants, though closely proportional to them) and the lower curve

sun-spot numbers. It will be noticed that in their most pronounced features the two curves have but little in common, and that the great drops in the pyrheliometric values occur simultaneously with violent volcanic explosions, as already explained, and not at the times of sun-spot changes. *Hence it appears that the dust in our own atmosphere, and not the condition of the sun, is a very important, if not the controlling, factor in determining the magnitudes and times of occurrence of great and abrupt changes of insolation intensity at the surface of the earth.*

FIG. 2.



Relation of pyrheliometric values to sun-spot numbers and volcanic eruptions.

Temperatures at the Surface of the Earth.—If a veil of dust actually should intercept as much as one-fifth of the direct solar radiation, as Fig. 1 indicates that at times it does, it would seem that in those years the temperature of the atmosphere at the surface of the earth should be somewhat below the normal. Of course, the great supply of heat in the ocean would produce a lag in this effect, particularly over the oceans themselves, and, besides, there must be both an increase of sky light by scattering and some interception of earth radiation by the dust which, since it is at great altitudes, receives the full, or nearly the full, planetary radiation of the earth. This increase of sky radiation, together with the return terrestrial radiation, obviously compensates in

some measure for the loss of direct insolation. However, measurements made by Abbot [28] at Bassour, Algeria, during the summer of 1912, show that at this time and place the direct radiation and the sky radiation, which obviously included both the scattered solar radiation and some return terrestrial radiation, were together less by about 10 per cent. than their normal combined values; and there is no reason to think that in this respect Bassour was at all different from other places, certainly a large portion of the northern hemisphere, at least, covered by the veil of dust. Clearly, then, if this decrease in the radiation received were universal and should continue indefinitely, the ultimate radiation of the earth would also decrease to the same extent, or 10 per cent. Now, since the earth, or rather the water vapor of the atmosphere, radiates substantially as a black body and, therefore, proportionally to the fourth power of its absolute temperature, it follows that a 10 per cent. change in its radiation would indicate about a 2.5 per cent. change in its temperature. But the effective temperature of the earth as a full radiator, which it closely approaches, is about 256° A.[29] Hence a change of 10 per cent. in the radiation emitted would imply 6.4° C. change in temperature, an amount which, if long enough continued, would be more than sufficient to produce glaciation equal probably to the most extensive of any known ice age.

As above implied, not much lowering of the temperature could be expected to take place immediately; however, some early cooling over land areas might well be anticipated. To test this point the temperature records of a number of high altitude (together with two or three very dry) inland stations have been examined. High altitudes were chosen because it was thought that the temperature effects of dust in the upper atmosphere probably are most clearly marked above the very and irregularly dusty layers of the lower atmosphere; and the condition that the stations should also be inland was imposed because these are freer, presumably, than many coast stations, from fortuitous season changes. Thus, stations in the eastern portion of the United States were rejected because of the great differences in the winters, for example, of this section depending upon the prevailing direction

[28] *Smithsonian Miscellaneous Collections*, vol. lx, No. 29, 1913.

[29] Abbot and Fowle, *Annals Astrophys. Obsy.*, Smithsonian Institution, vol. ii, p. 175, 1908.

of the wind,[30] a condition wholly independent, so far as known, of variations in the intensity of direct radiation.

The number of stations was still further limited by the available recent data. Hence the records finally selected, and kindly put in shape by the Climatological Division of the United States Weather Bureau, Mr. P. C. Day in charge, were obtained at the following places:

TABLE II.

Stations Whose Data Were Used.

Name.	Latitude.	Longitude.	Elevation in feet.
AMERICA.			
Baker	44° 46′ N.	117° 50′ W.	3,466
Bismarck	46° 47′ N.	100° 38′ W.	1,674
Cheyenne	41° 08′ N.	104° 48′ W.	6,088
Denver	39° 45′ N.	105° 00′ W.	5,291
Dodge City	37° 45′ N.	100° 00′ W.	2,509
El Paso	31° 47′ N.	106° 30′ W.	3,762
Helena	46° 34′ N.	112° 04′ W.	4,110
Huron	44° 21′ N.	98° 14′ W.	1,306
North Platte	41° 08′ N.	100° 45′ W.	2,821
Red Bluff	40° 10′ N.	122° 15′ W.	332
Sacramento	38° 35′ N.	121° 30′ W.	69
Salt Lake City	40° 46′ N.	111° 54′ W.	4,360
San Antonio	29° 27′ N.	98° 28′ W.	701
Santa Fé	35° 41′ N.	105° 57′ W.	7,013
Spokane	47° 40′ N.	117° 25′ W.	1,929
Winnemucca	40° 58′ N.	117° 43′ W.	4,344
Yuma	32° 45′ N.	114° 36′ W.	141
EUROPE.			
Mont Ventoux	44° 10′ N.	5° 16′ E.	6,234
Obir	46° 30′ N.	14° 29′ E.	6,716
Pic du Midi	42° 56′ N.	0° 8′ E.	9,380
Puy de Dôme	45° 46′ N.	2° 57′ E.	4,813
Säntis	47° 15′ N.	9° 20′ E.	8,202
Schneekoppe	50° 44′ N.	15° 44′ E.	5,359
Sonnblick	47° 3′ N.	12° 57′ E.	10,190
INDIA.			
Simla	31° 6′ N.	77° 12′ E.	7,232

In Table III the first column gives the year in question. The second column gives the average departure in degrees F., for the seventeen American stations, of the annual average maximum, as determined from the monthly average maxima, from the normal annual maximum, or average of a great many annual average maxima. The third column gives smoothed values, determined from the actual values in the second column as follows:

[30] Humphreys, *Monthly Weather Review*, vol. xlii, p. 672, 1914.

$$S = \frac{a + 2b + c}{4},$$

in which S is the smoothed value, b the actual value pertaining to the particular year for which S is being computed, a and c the actual values for the next previous and the next succeeding years, respectively. The fourth and fifth columns give, respectively, the actual and the smoothed average departures of the annual average minima, while the sixth and seventh columns give the corresponding average departures of the annual average means.

TABLE III.

Average Temperature Departures from Temperature Normals.

AMERICA.

Year.	Maxima.		Minima.		Means.	
	Actual.	Smoothed.	Actual.	Smoothed.	Actual.	Smoothed.
1880	−1.3	+0.03	−1.8	−0.68	−1.7	−0.50
1881	+0.2	−0.30	+0.6	−0.20	+0.1	−0.48
1882	−0.3	−0.50	−0.2	−0.20	−0.4	−0.50
1883	−1.6	−1.33	−1.0	−0.70	−1.3	−1.15
1884	−1.8	−1.20	−0.6	−0.28	−1.6	−1.05
1885	+0.4	−0.18	+1.1	+0.43	+0.3	−0.30
1886	+0.3	+0.35	+0.1	+0.10	−0.2	−0.03
1887	+0.4	+0.38	−0.9	−0.45	0.0	+0.07
1888	+0.4	+0.53	−0.1	−0.13	+0.5	+0.53
1889	+0.9	+0.63	+0.6	+0.23	+1.1	+0.85
1890	+0.3	+0.15	−0.2	−0.05	+0.7	+0.58
1891	−0.9	−0.58	−0.4	−0.38	−0.2	+0.05
1892	−0.8	−0.85	−0.1	−0.33	−0.1	−0.20
1893	−0.9	−0.73	−0.7	−0.38	−0.4	−0.08
1894	−0.3	−0.55	+0.4	−0.18	+0.6	+0.13
1895	−0.7	−0.35	−0.8	−0.08	−0.3	+0.25
1896	+0.3	−0.18	+0.9	+0.28	+1.0	+0.45
1897	−0.6	−0.30	+0.1	+0.13	+0.1	+0.28
1898	−0.3	−0.65	−0.6	−0.45	−0.1	−0.13
1899	−0.8	−0.13	−0.7	−0.10	−0.4	+0.25
1900	+1.4	+0.78	+1.6	+0.90	+1.9	+1.23
1901	+1.1	+0.83	+1.1	+1.08	+1.5	+1.35
1902	−0.3	−0.13	+0.5	+0.38	+0.5	+0.53
1903	−1.0	−0.43	−0.6	−0.05	−0.4	+0.18
1904	+0.6	−0.15	+0.5	+0.05	+1.0	+0.38
1905	−0.8	−0.30	−0.2	+0.08	−0.1	+0.33
1906	−0.2	−0.30	+0.2	+0.08	+0.5	+0.33
1907	0.0	+0.10	+0.1	+0.10	+0.4	+0.50
1908	+0.6	+0.15	0.0	−0.08	+0.7	+0.43
1909	−0.6	+0.38	−0.4	−0.05	−0.1	+0.55
1910	+2.1	+0.80	+0.6	+0.08	+1.7	+0.75
1911	−0.4	+0.03	−0.5	−0.35	−0.3	+0.05
1912	−1.2	−0.70	−1.0	−0.63	−0.9	−0.53

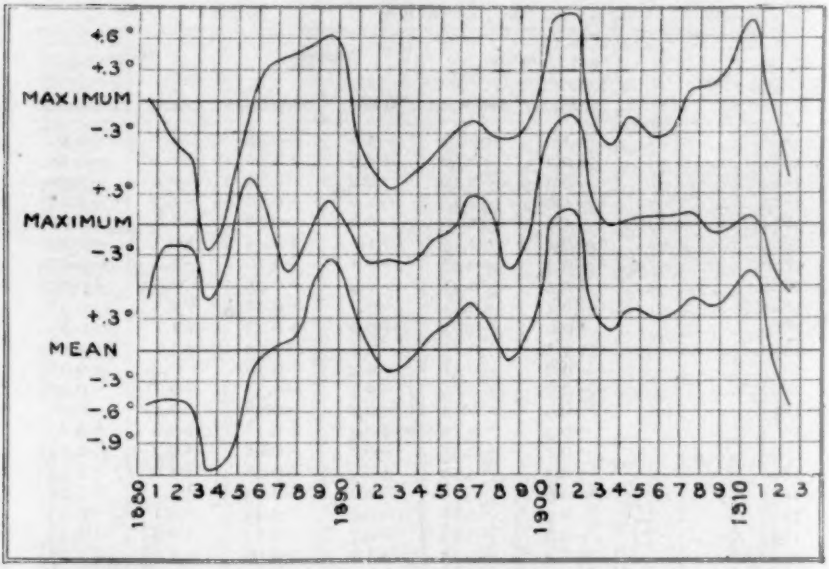
Fig. 3 shows the graphical equivalents of the smoothed portions of Table III.

It will be noticed that the three curves of Fig. 3, marked

maximum, minimum, and mean, respectively, are, in general, quite similar to each other. Hence, because of this mutual check and general agreement, it seems reasonably certain that any one set of temperature data, the means, for instance, furnishes a fairly safe guide to the actual temperature and climatic fluctuations from year to year or period to period.

Table IV gives the weighted actual average departures and the smoothed departures in degrees F. of the annual mean tem-

FIG. 3.



Smoothed averages of the annual average temperature departures of 17 American stations.

peratures of the selected seventeen American, seven European, and one Indian stations listed in Table I.

The average departures were calculated in accordance with the more or less correctly coefficiented equation,

$$D = \frac{4A + 2E + I}{7},$$

in which D is the weighted departure, A the smoothed average American, E the smoothed average European, and I the smoothed Indian, departure of the mean annual temperature from the normal annual temperature.

(To be concluded)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

MATERIALS AND METHODS USED IN THE MANUFACTURE OF ENAMELED CAST-IRON WARES.[1]

By Homer F. Staley.

[ABSTRACT.]

THIS is a comprehensive treatise dealing with the various phases of the technology of manufacturing enameled cast-iron wares. It is the first publication dealing fully with this subject in any language.

The paper deals particularly with the coating of cast iron with white vitreous enamels by the American or dry-powder process. In this method of manufacture, the thoroughly cleaned castings are painted with a suspension in water of powdered glass, clay and other materials. This suspension is known as the ground coat. The castings are then heated until the ground coat is thoroughly fused, forming an extremely thin layer of transparent glass on the castings. The ware is then withdrawn from the furnace and immediately coated by means of long-handled sieves with a layer of white, opaque, powdered glass, known as the cover coat enamel. Next the castings are returned to the furnace, and in a couple of minutes the cover coat enamel fuses to a smooth layer. Two such layers of cover coat enamel are usually applied, giving a total thickness of from $^1/_{32}$ to $^1/_{16}$ of an inch. The paper does not discuss the enameling of cast iron with wet coat cover enamels.

Several sections are devoted to a discussion of the preparation and testing of the various chemicals and minerals used in compounding enamels and to the effect each of these has on the physical and chemical properties of enamels. The methods employed in making and cleaning the castings are described in detail, beginning with construction of patterns and ending with sand blasting and polishing. The methods and equipment, including furnaces, used in preparing enamels and applying them to castings are covered in two sections. Sections are devoted to the control of the

* Communicated by the Director.

[1] Technologic paper 142.

lustre of enamels, the cause and control of crazing, and to the methods to be used in avoiding blisters, pin holes and other minor defects. Typical formulas are given for ground coat enamels, cover coat enamels containing oxide of tin, and for those containing antimony compounds as the opacifying agent. These formulas are each stated in terms of raw batch for 1000 pounds melted enamel, of percentage composition and of empirical chemical formula. The calculations involved in arriving at each form of expression are explained in detail.

A STUDY OF THE DETERIORATION OF NICKEL SPARK PLUG ELECTRODES IN SERVICE.[2]

By Henry S. Rawdon and A. J. Krynitzky.

[ABSTRACT.]

THE electrodes of spark plugs are usually made of commercial nickel wire, 97 per cent. grade being a common material. After considerable service, the electrodes show different types of deterioration. A peculiar one which occurs only in the side electrodes is the formation of transverse "knife-cut" breaks together with the intergranular embrittling of the metal adjacent to the break; a gradual widening of the breach results as a consequence. Such breaks were found only in the side electrodes which are firmly anchored at both ends. The central electrode shows an embrittling of the surface metal only at the extreme tip, as is also true of the type of side electrodes which are anchored at only one end.

This characteristic embrittling of the nickel wire appears to be due to a combination of causes. Microscopic examination of the deteriorated wires shows a complete network of intercrystalline fissures in the embrittled portions after etching. Often intercrystalline cracks extend deep into the wire. The cohesion between the adjacent grains is greatly weakened and crystals often fall bodily out of place upon slight etching.

Continuous heating of nickel wires for several days at a high temperature (approximately 850° C., 1562° F.) develops an intercrystalline eutectic-like network, apparently of oxide, in the outer zone of the wire. While this aids in the embrittling of such wires, it probably does not contribute to the deterioration of the electrodes of spark plugs. Heating in reducing gases,

[2] Technologic paper 143.

similar to those encountered in service, develops a similar intergranular network. Intense local heating, by means of the electric spark, does likewise in a small overheated zone. Both of these causes probably contribute materially to the embrittling of the electrodes in service.

The application of a relatively very low tensional stress (approximately 5 per cent. of the ultimate strength of the normal material) was found sufficient to fracture nickel wires when hot. Wires broken in this way show a sharp crystalline fracture with no elongation whatever and in every respect the appearance is identical with the breaks produced in service. The central electrode is found to deteriorate much less than the side ones. The latter, when anchored at both ends across the shell of the plug, are subject to tensional stress due to the differential expansion of the shell and hence the cracks develop quite readily. Evidently this deterioration of nickel wire is a characteristic behavior of this material at high temperatures.

THE CADMIUM ELECTRODE FOR STORAGE BATTERY TESTING.[3]

By H. D. Holler and J. M. Braham.

[ABSTRACT.]

IN the operation and testing of storage cells, it is frequently important, particularly in cases of low capacity, to know the individual potentials of the positive and negative plates of the cell. No standard method of measuring the potentials of storage battery plates is recognized, but for many years the common method has consisted in measuring the potential differences between either plate and a piece of metallic cadmium with an ordinary voltmeter. This method often leads to contrary results and voltmeters vary greatly in resistance. The Bureau undertook this investigation to determine the accuracy of the cadmium electrode and the errors to which it is subject. As a standard electrode, the mercurous sulphate half-cell was adopted after experiments which showed it to be well adapted to the purpose. The reproducibility of the cadmium electrode was first determined and then the effect of temperature, the effect of drying the electrodes and the polari-

[3] Technologic paper 146.

zation of the electrode were studied. The constancy of the cadmium electrode during measurements of the potentials of storage battery plates when on charge and discharge was also determined. This investigation deals only with the accuracy of the cadmium electrode and does not discuss the cadmium readings with reference to the age or the condition of the battery.

The most important error found was due to the polarization of the electrode but this error can be easily avoided if the electrode is used to measure the potential of the negative plate from which the potential of the positive plate may be calculated if the cell voltage is known. This is contrary to the way the electrode is generally used, but it eliminates the chief error which arises when the ordinary voltmeter is employed to measure the voltage.

THE DEPENDENCE OF THE INPUT IMPEDANCE OF A THREE-ELECTRODE VACUUM TUBE UPON THE LOAD IN THE PLATE CIRCUIT.[4]

By John M. Miller.

[ABSTRACT.]

BECAUSE of the capacities between the electrodes of three-electrode vacuum tube, the input impedance, which determines the input voltage supplied to the grid of the tube by the apparatus in the input circuit, depends upon the electrical characteristics of the plate or output circuit. In this paper theoretical relations are established which permit the input impedance to be calculated when the impedance in the plates circuit is known. These relations are also checked by experiment.

THERMAL EXPANSION OF INSULATING MATERIALS.[5]

By Wilmer H. Souder and Peter Hidnert.

[ABSTRACT.]

THIS paper gives data on a few materials possessing irregular or unusual expansive properties.

In most cases the expansions are too irregular to justify the use of the general quadratic equations.

[4] Scientific paper 351.

[5] Scientific paper 352.

A knowledge of the thermal behavior of these materials is essential before assembling them in certain types of apparatus subjected to wide temperature variations.

The most striking peculiarities are:

(*a*) The wide range in the values of the coefficient of porcelain (from 1.6 to 19.6 millionths per unit length per degree Centigrade).

(*b*) The three varieties of expansions for porcelain; namely, straight line, concave and convex expansion curves.

(*c*) The shrinkage and the loss in weight of the phenol and similar compounds when subjected to excessive heat treatment.

(*d*) The permanent growth and variations of different marbles when subjected to heat treatment.

(*e*) The negative coefficient of expansion of marble at low temperatures.

VARIATION IN DIRECTION OF PROPAGATION OF LONG ELECTROMAGNETIC WAVES.[6]

By a Hoyt Taylor, U. S. Naval Aircraft Laboratory.

[ABSTRACT.]

THE observed direction of radio waves as obtained with a direction-finder varies with time, when long waves are used such as those of very high-power stations. The variations of direction are of the order of 90° for very long waves. No such large variations are found for short damped waves produced by spark apparatus. A method of increasing the sharpness of determination of direction has been worked out. A theoretical explanation of the variations of directions is given, based on the existence of media in the earth's atmosphere capable of reflecting and refracting the waves.

PRINCIPLES OF RADIO TRANSMISSION AND RECEPTION WITH ANTENNA AND COIL AERIALS.[7]

By J. H. Dellinger.

[ABSTRACT.]

COIL aerials are coming to replace the large antennas in radio work. The advantage of the coil aerial as a direction-finder interference preventer, reducer of strays and submarine aerial, make it

[6] Scientific paper 353.

[7] Scientific paper 354.

important to know how effective such an aerial is as a transmitting and receiving device in comparison with the ordinary antenna. In this article the mathematical theory is presented and, as a result, the answer to this question is obtained. Experiments have verified the conclusions reached, and the formulas which are obtained are a valuable aid in the design of an aerial to fit any kind of radio station.

A great many questions and hazy ideas on the behavior of radio waves are cleared up by the study which was made and here presented.

It is found that the coil aerial is particularly desirable for communication on short wave-lengths. A coil aerial is as powerful as an antenna only when its dimensions approach those of the antenna. For other reasons, however, a small coil aerial is in many cases as effective as a large antenna.

It is shown that an advantageous type of radio aerial is a condenser consisting of two large metal plates. This type of aerial has many of the advantages of the coil aerial.

The fundamental principles of design of aerials are given in this paper. On the basis of this work the actual functioning of any type of radio aerial can be determined either from measurements made upon the aerials or from actual transmission experiments.

The investigation has opened up a large and most interesting field for further research and progress in the utilization of radio waves.

DETERMINING THE OUTPUT CHARACTERISTICS OF VACUUM-TUBE GENERATORS.[1]

By Lewis M. Hull.

[ABSTRACT.]

THE direct-coupled, Hartley circuit can be taken as typical of the circuits used in connection with the three-electrode vacuum tube for the purpose of generating oscillations. The grid and filament of the tube in this particular circuit are connected to the branched circuit containing inductance and capacity in such a manner as to include a portion of the inductance of that circuit; the rest of the inductance of the circuit is included between the

[1] Scientific paper 355.

plate and filament, while a capacity and resistance, representing the antenna, is connected between grid and plate. Power is supplied to the circuit from a high-voltage battery or generator, which is connected in series with the plate, filament, and branched output or oscillatory circuit. When the system is in oscillation, power from the direct-current source is converted into oscillating-current power; the oscillating current flows in series through the capacity and coils of the branched circuit, its wave form being practically sinusoidal, and its frequency of oscillation being the natural or resonant frequency of the branched circuit. This current induces sinusoidal oscillating voltages across the plate and grid coils having a definite constant ratio of amplitudes, and so related as to phase that when the grid is e volts positive or negative with respect to the filament, the plate is $(E_b - ne)$ volts positive or $(E_b + ne)$ volts positive, E_b being the steady supply voltage, and n, the ratio of plate and grid coupling reactances. Under the influence of these sinusoidal voltages a pulsating electron current flows in the grid-filament circuit whose fundamental constituent is in phase with the alternating grid voltage; this current represents a withdrawal of power from the output circuit. Likewise a pulsating current flows in the plate-filament circuit whose fundamental constituent is opposite in phase to the alternating component of plate voltage; this current supplies power to the output circuit. A conduction of stability ensues when the power supplied by the fundamental of plate current minus the power dissipated by the fundamental of grid current is just equal to the power dissipated by the output current in the resistance of the antenna.

The fundamental constituents of the electron currents which will be supplied by a given tube under the action of sinusoidal plate and grid voltages can be computed as functions of these voltages from a family of "static characteristics" of the tube which are obtained by varying these voltages step by step and measuring the resulting steady values of current. The effective power output is

$$P_o = \frac{nE_g}{2}\left(I_p - \frac{1}{n}I_g\right)$$

where E_g is the amplitude of grid voltage and I_p and I_g are the amplitudes of the fundamentals of plate and grid currents, respectively. The efficiency is

$$Y = .5\,\frac{E_g}{E_b}\left(\frac{nI_p - I_g}{oI_p}\right)$$

where E_b is the steady supply voltage and oI_p is the reading of a direct current ammeter in the plate circuit.

From the current characteristics the power output can be obtained graphically as a function of the grid voltage:

$$P_o = f(E_g)$$

Moreover,

$$E_g = L_g \sqrt{\frac{P_o}{RCL}}$$

Where L_g is the grid inductance and R, C, L, are the total resistance, inductance, and capacity of the antenna circuit. A simultaneous graphical solution of these two equations gives the power output from the tube as a function of any of the three electrical constants of the output circuit.

Such solutions can be obtained graphically for any type of tube whose static characteristics are known.

Twenty-three Types of Optical Glass. R. J. MONTGOMERY. (*American Ceramic Society,* September 24, 1919.)—A distinction should be made between optical and other kinds of glass. By the word optical we mean those glasses which are selected for certain purposes because of their behavior toward transmitted light. This behavior is primarily due to its composition and not to its shape. Measurements of the index of refraction and dispersion classify the optical glasses into sub-divisions. In ordinary glass the composition may be changed to obtain satisfactory melting qualities, but in optical glass each change in composition will change the optical properties. On this account optical glass is much more difficult to make as the optical properties must be held constant within very narrow limits.

One hundred or more optical glasses have been listed, but practically all of them may be placed in 23 groups. The ones in each group are quite similar in composition and in method of manufacture. They may be shown graphically by plotting the index of refraction against dispersion on coördinate paper. The index of refraction may vary from about 1.45 to 1.96, while the dispersion may vary from about 20.0 to 70.0. From the plotted information it is easy to determine the fields in which each glass constituent is used in the largest amount. We, therefore, have the lead field, the barium field, the soda-lime field, the boric acid field, etc. Approximate compositions are apparent and new glasses may be developed by interpolation between the compositions of known glasses.

NOTES FROM THE LABORATORY, GENERAL ELECTRIC COMPANY.*

THE IONIZATION GAGE.

By S. Dushman and C. G. Found.

[ABSTRACT.]

I. *Construction and Calibration.*—The design used by the writers consists of two concentric tungsten filaments inside a coaxially situated cylinder. The inner filament is used as a source of electrons with the outer one as anode, while the cylinder is used as positive ion collector. The gage was calibrated by a "flow" method (based on Knudson's formula for the flow of gases through capillaries) for extremely low pressure, and it was found that the electron emission is proportional to the pressure over a range which extends from over 10 bars to 10^{-3} bars, and it is, therefore, probably certain that this same relation holds at the lowest attainable pressures.

II. *Relation between Ionization Current at Constant Pressure and Number of Electrons per Molecule of Gas.*—Calibration of the gage with different gases led to the interesting relation that the number of positive ions formed at constant electron emission and constant pressure is proportional to the number of electrons per molecule of the gas ionized. It is possible, therefore, by this method to determine *molar numbers* for different gases. By molar number is meant the sum of the products, atomic number times number of atoms taken for each atom in the molecule. Thus the molar number of iodine is $2 \times 53 = 106$; and for HgI_2 it is $80 + 2 \times 53 = 186$. Vapor pressure determinations of both these substances gave results agreeing with the above values for the molar numbers. If it be assumed that ionization is due to collisions between thermions and electrons in the atoms, it is possible to calculate the mean free path of an electron in any gas at a given pressure, and also the effective diameter of the electron. For argon at 1 bar pressure and room temperature, the mean free path is about 150 cm., and the diameter of the electron is calculated on this basis as about 4.4×10^{-9} cm.

* Communicated by the Director.

Biochemical Studies of the Diet.—In a paper on the relation of the diet to pellagra, E. V. McCOLLUM (*Proceedings of the American Philosophical Society*, 1919, vol. lviii, pp. 41–54) gives a summary of recent biochemical discoveries concerning a satisfactory diet. The diet must furnish sufficient energy in the form of carbohydrates, fats and proteins, an adequate supply of mineral food or ash in suitable combinations, and a sufficient amount of the two food hormones, or vitamines fat-soluble A and water-soluble B. The proteins must be suitable in both quality and quantity; quantitatively the ration should contain a liberal amount of protein; qualitatively the value of a protein depends on its source, those of the navy bean or pea are less valuable than those of the cereal grains, and these in turn less valuable than those of milk. The food hormones are dietary essentials, as yet unidentified chemically; absence of fat-soluble A from the diet produces a diseased condition of the eye known as xerophthalmia, while absence of water-soluble B gives rise to the disease beri-beri. A satisfactory diet cannot be obtained from mixtures of seeds or products obtained by their milling with tubers, edible roots, and cuts of meat consisting of muscle; in addition one or more of the protective foods must be eaten. The group of protective foods includes milk, eggs, and leafy vegetables; by virtue of their inorganic content of fat-soluble A, and the quality of their proteins, they insure the presence of a sufficient amount of these ingredients in the diet if they be used in sufficient quantity; they thereby protect the health, hence their name protective foods. If foodstuff or mixture of foodstuffs may be analyzed by the biological method, it is fed to a group of animals, such as rats, while other groups receive it supplemented by pure protein, or salts, or a food hormone, etc., the influence of the various rations on the weight and health of the experimental animals is then observed. Pellagra is caused by an infectious agent, and not by a faulty diet, however such a diet may increase the susceptibility to this disease. J. S. H.

Steel Disk Automobile Wheels. (*Scientific American*, vol. cxxi, p. 225, September 6, 1919.)—There is a growing tendency on the part of motorists to favor the pressed steel disk wheel and increasing numbers of fine cars are being equipped with traction and support members of this type. The wheel used for passenger cars is a single disk type, being dished for strength. In most designs the thickness of the metal is greater at the centre than at the rim, thus proportioning the section to the strain coming upon it. A cast-steel master hub is fastened to the axle, and the steel disk is attached to this by four easily removable nuts which screw on studs in the permanent hub flange. The disk wheel is as easily removed as any other type and is stronger and more easily washed than the conventional wood or wire spoked forms.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

PHTHALIC ANHYDRIDE. I. INTRODUCTION.[1]

By H. D. Gibbs.

[ABSTRACT.]

PHTHALIC ANHYDRIDE, a valuable intermediate for the manufacture of certain important dyes and medicinals, is usually made by the oxidation of naphthalene by means of sulphuric acid in the presence of mercury compounds as catalysts. This method is not as satisfactory as might be desired, since the yields are poor and erratic, generally averaging about 25 per cent. theoretical but occasionally running as high as 55 per cent.

It had been previously found that toluene vapors can be oxidized by passing a mixture of them with oxygen or air heated to a temperature varying from the boiling point of toluene to 550° C. over oxides of the fifth and sixth groups of the periodic system, especially vanadium oxide and molybdenum oxide. Under these conditions the toluene is oxidized to benzaldehyde and benzoic acid, the former predominating. Similar reactions with (1) naphthalene vapors and air produce phthalic anhydride, with (2) anthracene and air, anthraquinone and with (3) phenanthrene and air, phenanthraquinone. Since the demand for phthalic anhydride was acute, this problem was the first one thoroughly investigated.

The best laboratory yield was 82 per cent. theoretical, or about 95 grams of phthalic anhydride from 100 grams of naphthalene. A small scale factory unit set up in the laboratory produced about 150 grams of phthalic anhydride in one hour. A notable fact in regard to this method is the remarkable degree of purity of the phthalic anhydride.

The Department of Agriculture is coöperating with chemical manufacturers on this process, which, it is believed, once all the details are worked out, will be the most economical and practicable method known for making phthalic anhydride, and this compound may become one of the cheapest organic compounds.

* Communicated by the Chief of the Bureau.

[1] Published in *J. Ind. Eng. Chem.*, vol. xi, No. 11, Nov., 1919, pp. 1031, 1032.

Scientific Research in Relation to the Glass Industry. EDWARD W. WASHBURN. (*American Ceramic Society,* September 29, 1919.)—With the development of methods of producing, controlling and measuring high temperatures in the laboratory our knowledge of the chemistry and physics of high temperature processes has steadily increased and applications of that knowledge have naturally followed. The stimulus of the war has aided greatly in bringing together the practical man of the factory and the scientist of the laboratory. But in glass-making we know *how* to-day much better than we know *why*. Progress demands that we know why. In industrial laboratories the work to be done may be roughly classified under three headings: (1) Routine testing of raw materials and products and similar control work; (2) works problems, including the curing of troubles and the improvement of processes and products; (3) fundamental research to find out the *why* of the operations or to secure quantitative scientific data covering materials, processes and products In the glass industry almost all of the fundamental research work remains to be done. For example, very little is known of the relations between (1) viscosity and (2) temperature and composition, although viscosity has long been recognized as of great importance in making and working glass. Surface tension and vapor pressure and even density have scarcely been studied at all. Of the reactions and compounds we know almost nothing. The nature of gases remaining in solution is almost unknown, as well as their effect, if any, on the properties of the glass. Many unanswered questions are referred to, including relations between composition and properties, cause of greenish color resulting from substituting soda for potash, the condition of copper in glass, the cause of pink color from manganese, and red in chrome pink, the function of arsenic. There are three types of laboratories to carry out such researches: (1) industrial, (2) government or research foundations, and (3) university. The endowment of research professorships in glass would have a very stimulating effect.

The Penetration of Iron by Hydrogen. T. S. FULLER. (*American Electrochemical Society,* 1919.)—The results are given of experiments showing the effect of various conditions on the penetration of iron by nascent hydrogen at temperatures from 20° to 100° C. Hydrogen was generated on the outside of an iron tube by immersing the tube in a solution, and the volume of gas penetrating to the inside of the tube was measured. The rate was greater for a unit immersed without electrical connections than when the unit was used as a cathode, but in the latter case the greater the current the greater the penetration. The rate also increases with the temperature. Copper is not penetrated, but a coating of tin on the iron increases the rate. The effects of other conditions are shown. G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES*

WHY AND HOW COKE SHOULD BE USED FOR DOMESTIC HEATING.

By Henry Kreisinger and A. C. Fieldner.

COKE should be used for domestic heating because it is a smokeless fuel. Estimates of the cost of smoke to the community are given as $12 per capita per year in Cleveland and $20 per capita per year in Pittsburgh. The use of small sizes of coke for domestic heating gives a better return to the coke producers and encourages the production of coke and its by-products, which is an advantage to the nation as compared to burning raw bituminous coal as fuel. It makes more gas available to the householder, with its resulting convenience and economy. The ammonia that is made as a by-product of coke is used for fertilizer and helps to keep down the price of food. Coal-tar from coking furnaces is the raw material from which many drugs, dyes, paints, preservatives, roofing, road dressing and a myriad of other substances are made. Increasing the supply of the raw material helps keep down the price of the finished product. In addition, a coke fire is easier to tend and makes less dirt in the house. Learning how to manage a fire when coke is burned is a relatively simple matter that is described in detail in Technical Paper 242, Bureau of Mines, which is sent free on request.

THE VAPOR PRESSURE OF LEAD CHLORIDE.

By E. D. Eastman and L. H. Duschak.

THE vapor pressure of the chloride of lead, and of other metals with which it is associated in nature, is a matter of interest to the metallurgist because it seems possible that the problem of economical treatment of the complex ores of lead, zinc, silver, and copper may be solved through the use of processes involving a chloridizing roast and subsequent volatilization of part or all of the valuable metallic constituents. To successfully develop such processes an

* Communicated by the Director.

accurate knowledge of the fundamental data, such as vapor pressures of the metals involved, is essential.

The material to be studied was heated in a hand-regulated electrical furnace, using an apparatus devised for the purpose. The heating was carried on in an atmosphere of nitrogen, prepared by the Lupton method. The weight of lead chloride recovered was determined by steaming out the condenser tube and titrating for chloride by the Volhard method.

The results of the investigation are given in Technical Paper 225 of the Bureau of Mines. They form a smooth curve between the values of 0.141 mm. of mercury at 500° C. to 600 mm. mercury at 925° C. The melting point of lead chloride is determined as 495° C. and the boiling point at 945° C. at a pressure of 754 mm. of mercury. The heat of vaporization of lead chloride at the melting point is calculated to be 40,600 calories. The vapor pressure of solid lead chloride, down to 400° C. are calculated and shown graphically. Details of the methods used and results obtained are given in the publication referred to above.

AN ANALYTICAL METHOD FOR DETECTING BLOWN-OUT SHOTS IN COAL MINES.

By G. F. Hutchison and Jacob Barab.

A BLOWN-OUT shot is the term applied to the detonation of a charge of explosive, intended to break down coal, or other mineral, when the explosion takes place much as it would in a gun-barrel, without causing much rupture of the material surrounding the charge. In investigating a coal-mine explosion, it is often desirable to ascertain whether a blown-out shot occurred, and, if so, what was the nature of the explosive used. It was determined by experiment that if the loose material within or about the collar of the hole is removed, the hole sampled, and scraped throughout its entire length, this material combined into a sample totaling at least half a pound, and the sample analyzed qualitatively and quantitatively, both the fact of an explosive having been fired in the hole, and also the general character of the explosive could be determined by comparing the results of the analysis with the analysis of coal taken from the same seam at a point as close as practicable to the hole. It is not, of course, possible to dis-

tinguish between explosives of similar composition, but as only a few kinds of explosives are usually used in an individual mine, it is usually practicable to distinguish between them. The method is not an exact one, but affords welcome aid in determining the causes of a mine explosion. Details of the method used are given in Technical Paper 210, U. S. Bureau of Mines.

MINOR NOTES.

The Bureau of Mines is coöperating with Denver University in research on radium emanation and to date about 30 of the principal spectral lines of radium emanation have been established with certainty. About 20 of these lines coincide with the principal lines observed by other authorities, and the remainder seem to be new. Further work will be done to ascertain whether the large number of lines found by Rutherford all belong to the radium emanation spectrum.

At the Denver station of the Bureau two successful methods have been developed for the determination of copper in the presence of molybdenum. Three methods for the determination of molybdic acid in the presence of molybdenite were tried with successful results.

Studies at the Pittsburgh station upon the effect of solutions containing chromates upon the corrosion of steel, copper, and cupro-nickel indicate that it is possible to make steel passive without preventing the corrosion of copper and cupro-nickel in ammonia solutions.

California 220,000-volt, 1100-mile, 1,500,000-kw. Transmission Bus. R. W. Sorenson. (*Proc. Am. Inst. Elec. Engs.*, September, 1919.)—In California small developments now produce a total of 325,000 kw. Four large projects can be developed to give 1,500,000 kw. within a few years.

For five years transmission has been successful in the southern part of the state at 150,000 volts. To distribute the output of the four plants the author suggests a two-circuit transmission system from Pit River in the north to Los Angeles with branch lines, 60 cycles, 220,000 volts. Thus all the power stations of the state would be linked together.

G. F. S.

Mechanical Lifting Devices. DANA WEBSTER. (*National Safety Council,* 1919.)—Lifting devices were undoubtedly used by Julius Cæsar, as far back as 265 B.C., as history mentions their lifting animals from the dens in the arena in the Coliseum of Rome. About the middle of the nineteenth century platforms or cable-hoisted elevators were first installed in New York and Boston, but were not provided with any kind of safety devices, and strange to say, you can find a few elevators without safety devices at the present time.

A few years later elevators were equipped with safety devices of such type that it was necessary for the hoist cable to break before the safety could actuate. There are a great many of this type of safety in use to-day, but with the introduction of high-speed elevators which are required to meet the demands of the public, quite naturally it necessitated much better type of safety apparatus and a multiplicity of cables.

Accidents could and did occur from over-speeding elevators caused by disarrangements of the controlling apparatus, and it became necessary to provide safety devices that would actuate should the elevator speed increase beyond a predetermined number of feet per minute.

The most essential elements of safety are the prevention of excessive speed from any cause, the over-running of the limits of travel at top and bottom, safe protection at the landing entrances to the elevator, and a regular examination of the cables and all parts of the elevator equipments. A. R.

Aerial Fire Patrol. (*Weekly News Letter, U. S. Department of Agriculture,* vol. vii, No. 6, p. 8, September 10, 1919.)—The airplane forest fire patrol conducted in the National Forests in California by the Army Air Service in coöperation with the Forest Service of the United States Department of Agriculture has been extended to cover a portion of the forests in Oregon. Headquarters have been established at Salem, Ore., and the operating squadron for the present will consist of five officers and seven enlisted men operating eight airplanes. The city of Portland has donated a landing field and will construct a hangar. Patrol routes in the Oregon and Santiam Forests are now being worked out.

One of the Army aviators in the fire-patrol work recently made a successful flight to the floor of the Yosemite Valley. To make a landing the aviator had to gain an altitude of 11,000 feet and spiral down between the walls of the canyon, which are 5000 feet high and a quarter of a mile apart. The landing was difficult because of high trees and wires. This exploit was of much interest to forest officers, as it is thought to have been a step toward the more extended use of airplanes in the forests, where landing places in the mountains are comparatively few.

A. R.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting Held Wednesday, November 19, 1919.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 19, 1919.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to the membership since last report, 9.

The following gentlemen nominated by the Board of Managers for Corresponding Membership were unanimously elected:

Dr. A. S. Eve, Professor of Physics, McGill University, Montreal; Dr. John S. Townsend, Professor of Physics, Oxford University; Professor Charles Fabry, Professor of Physics, University of Marseilles.

Reports of progress were presented by the Committee on Library, and the Committee on Science and the Arts.

The Chairman then announced that the next business of the Meeting would be the presentation of the medals and certificates to the gentlemen whose inventions had been examined, by the Committee on Science and the Arts, and found worthy of recognition by the Institute.

Mr. Benjamin Franklin, Chairman of the Committee on Science and the Arts, then introduced Mr. Harvey D. Williams and Mr. Reynold Janney, who had been recommended jointly for the award of the Potts Medal, for their inventions embodied in what is known as the "Waterbury Hydraulic Speed Gear." The President then presented the medals and certificates to Messrs. Williams and Janney.

Mr. Clarence P. Landreth, of Philadelphia, whose "Electrolytic Sewage Process" had also been recommended for the award of the Potts Medal, was next introduced, and the medal and accompanying certificate were presented to him by the President.

Mr. Franklin was again recognized, and described the invention in the art of radiography, made by Mr. H. Clyde Snook, of New York City. Mr. Snook was recommended for the award of the Edward Longstreth Medal of Merit, and this with the accompanying certificate was presented to him by the President.

Rear Admiral J. A. Hoogewerff, U. S. N., Superintendent of the U. S. Naval Observatory, Washington, D. C., then presented the paper of the evening, entitled "The Relation of the U. S. Naval Observatory to the Navy and Shipping Interests of the Country." The speaker referred to the dependence of the sailor on the practical applications of astronomy, and gave an account of the work of the U. S. Naval Observatory. After reviewing, briefly, the history of the Observatory, he described its various activities, including its time service, the publication of the American Ephemeris and Nau-

tical Almanac, its work in connection with navigational instruments, and its library. The war-time activities of the Naval Observatory were also reviewed. The subject was illustrated by lantern slides. After a brief discussion, the thanks of the Meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, November 5, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 5, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following report was presented for first reading:

No. 2713: Kemp Gas System.

A report was presented by the Special Committee on the Louis Edward Levy Memorial.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, October 23, 1919, at 8 o'clock, with Dr. George S. Crampton in the Chair. The minutes of the previous meeting were approved as published.

Augustus Trowbridge, Ph.D., D.S.M., D.S.O., Chev.L.H., Professor of Physics in Princeton University, and late Lieutenant Colonel of Engineers, attached to the General Staff and in technical charge of Sound and Flash Ranging in the American Expeditionary Force, delivered an illustrated lecture on "Flash and Sound Ranging Apparatus for the Location of Guns." The development of modern methods for locating the position of enemy artillery, and directing the fire of friendly artillery was traced. A description was given of the principles of both flash and sound ranging, the methods and apparatus used by the ranging troops of the American Expeditionary Force in France, and the quality and quantity of the information thus obtained. The paper was discussed; a vote of thanks was extended to Doctor Trowbridge, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday evening, October 30, 1919, Mr. W. C. L.

Eglin and Prof. C. E. Clewell presiding jointly. The paper of the evening on "Wireless Telephony" was presented by Mr. N. H. Slaughter, of the Engineering Department, Western Electric Company, New York City, and formerly Lieutenant Colonel Signal Corps, U. S. A. The speaker reviewed briefly the pre-war development of radio telephony, and gave a summary of its war-time development and application. The Airplane Radio Telegraph Set used by the Army was described in detail and was illustrated by lantern slides and specimens of apparatus. An outline of the future uses and possibilities of Radio Telephony in military and commercial fields was also given, as well as its applications in aviation. After a brief discussion the thanks of the meeting were conveyed to the speaker.

R. B. OWENS,
Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section with the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, November 6, 1919, at 8 o'clock. Dr. Harry F. Keller, on behalf of the Section, and Mr. Samuel S. Sadtler, on behalf of the American Chemical Society, presided jointly. The minutes of the previous meeting were read and approved.

Bernhard C. Hesse, Ph.D., of New York City, presented a communication on "American Dye Industries—Present and Future." The world position of this industry in 1913 and at the present time were contrasted. The competitive conditions of the present and those to be expected in the near future were summarized. An outline was given of the protective legislation required to insure in this country a self-contained and self-sustaining coal-tar chemical industry in all its more important ramifications.

The paper was discussed. On motion of Dr. Walton Clark, a vote of thanks was extended to Doctor Hesse. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, November 12, 1919.*)

RESIDENT.

MR. GEORGE W. BIRCH, Chemist, 1414 Columbia Avenue, Philadelphia, Pennsylvania.

MR. FRANK H. GRIFFIN, Chief Chemist, The Viscose Company, Marcus Hook, Pennsylvania.

MR. EDWARD F. HENSON, Lumber Merchant, 921 North Delaware Avenue, Philadelphia, Pennsylvania.

MR. HOSFORD D. KELLOGG, Manager, The H. B. Smith Company, 17th and Arch Streets, Philadelphia, Pennsylvania.

MR. FRANK G. KENNEDY, JR., President, Logan Iron and Steel Company, 1218 Stephen Girard Building, Philadelphia, Pennsylvania.

MR. W. LEIGH SMITH, Chemist, The Viscose Company, and for mail, Box 171, Marcus Hook, Pennsylvania.

NON-RESIDENT.

DR. ROBERT R. TATNALL, Research Engineer, J. E. Rhoads & Sons, Wilmington, Delaware.

ASSOCIATE

MR. JUDSON T. BALLARD, Chemist, 6416 North 11th Street, Oak Lane, Philadelphia, Pennsylvania.

MR. KENNETH BRADDOCK-ROGERS, Haverford College, Haverford, Pennsylvania.

CHANGES OF ADDRESS.

MR. HENRY B. ALLEN, 8112 St. Martins Lane, Chestnut Hill, Philadelphia, Pennsylvania.

MR. J. EDWARD BARNHART, 407 Waldo Avenue, Pasadena, California.

MR. M. C. BURT, in care of Aetna Explosives Company, 165 Broadway, New York City, New York.

MR. CLARENCE R. CLAGHORN, in care of Vinton Colliery Company, 50 East 42nd Street, New York City, New York.

LIEUT.-COL. EDWARD B. CLARK, 61 Cedar Street, Chicago, Illinois.

MR. H. V. COES, in care of Ford, Bacon & Davis, 115 Broadway, New York City, New York.

DR. THOMAS D. COPE, Randal Morgan Laboratory of Physics, University of Pennsylvania, Philadelphia, Pennsylvania.

MR. ELLIOTT CURTISS, 429 North 13th Street, Philadelphia, Pennsylvania.

MR. S. B. ECKERT, Finance Building, 1428 South Penn Square, Philadelphia, Pennsylvania.

MR. E. W. FINKBINER, 207 Market Street, Newark, New Jersey

MR. W. E. FLETCHER, in care of Atlas Powder Company, 140 North Broad Street, Philadelphia, Pennsylvania.

MR. FRANK B. GILBRETH, 68 Eagle Rock Way, Montclair, New Jersey.

MR. MARTIN L. GRIFFIN, Mount Hope Finishing Company, North Dighton, Massachusetts.

MR. TABER HAMILTON, 1335 West Main Street, Louisville, Kentucky.

MR. GEORGE R. HENDERSON, The Aldine Hotel, 1920 Chestnut Street, Philadelphia, Pennsylvania.

MR. ROBERT E. HORTON, R. F. D. No. 1, Voorheesville, New York.

MISS EMILY F. HOWSON, 306 Woodlawn Road, Roland Park, Maryland.

COL. P. JUNKERSFELD, Stone & Webster Engineering Corporation, 147 Milk Street, Boston, Massachusetts.

MR. J. BENTON PORTER, General Electric Company, Equitable Building, 120 Broadway, New York City, New York.

MR. JANVIER RESINES, Racquet Club, Philadelphia, Pennsylvania.

MR. CHARLES E. RILLIET, in care of Washburn Continuation School, 655 West 14th Street, Chicago, Illinois.

MR. EDMUND G. ROBINSON, 909 Nottingham Road, Wilmington, Delaware.
MR. J. B. RUMBOUGH, P. O. Box No. 2, Asheville, North Carolina.
MR. FREDERICK W. SALMON, 1129 North 28th Street, Birmingham, Alabama.
MR. A. B. STITZER, in care of Republic Engineers, Inc., 60 Broadway, New York City, New York.
MR. JOHN STONE STONE, New Palace Hotel, San Diego, California.
DR. PAUL STRAUSS, 1030 Beverly Road, Brooklyn, New York.
MR. F. M. TAIT, 80 Broadway, New York City, New York.
MR. PAUL THOMPSON, N. W. Cor. Broad and Arch Streets, Philadelphia, Pennsylvania.
MR. B. C. TILGHMAN, Highfield, Dunham Road, Altrincham, Cheshire, England.
MR. C. C. TUTWILER, West Conshohocken, Pennsylvania.
MR. CARL D. ULMER, 1807 Fourth Street, S. E., Minneapolis, Minnesota.
MR. J. VALASEK, 1117 Seventh Street, S. E., Minneapolis, Minnesota.
MR. F. R. WADLEIGH, in care of Weston, Dodson & Company, Inc., 17 Battery Place, New York City, New York.
MR. PERCY WEDLAKE, 125 Atlantic Street, S. E., Washington, D. C.
MR. H. A. WILSON, Coronado Apartments, 22nd and Chestnut Streets, Philadelphia, Pennsylvania.
MR. H. D. WILSON, Coronado Apartments, 22nd and Chestnut Streets, Philadelphia, Pennsylvania.
MR. ROY V. WRIGHT, 398 North Walnut Street, East Orange, New Jersey.

LIBRARY NOTES.

PURCHASES.

Business Digest, July–December, 1918. Vol. vi.
CARD, S. F.—Air Navigation, Notes and Examples. 1919.
COLLINS, S. H.—Plant Products, and Chemical Fertilizers. 1919.
HUMPHREYS, A. C.—Lecture Notes on Some of the Business Features of Engineering Practice. 1916.
International Catalogue of Scientific Literature, vol. xiv. F—Meteorology, J—Geography. 1919.
JOHNSON, J. B.—Materials of Construction; Rewritten by M. O. Withey, and James Aston. 1918.
LINDGREN, WALDEMAR.—Mineral Deposits. 1919.
Reader's Guide to Periodical Literature, vol. iv. 1915–1918.
RIDEAL, E. K.—Industrial Electrometallurgy. 1919.
SCHOELLER, W. R., and POWELL, A. R.—Analysis of Minerals and Ores of the Rarer Elements. 1919.
SEIDEL, ATHERTON.—Solubilities of Inorganic and Organic Compounds. 1919.
SIBLEY, R., and DELANY, C. H.—Elements of Fuel Oil and Steam Engineering. 1918.
STEINHEIL, ADOLPH, and VOIT, E.—Applied Optics, vol. ii. 1919.

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Allen Cone Company, Bulletin No. 5. El Paso, Texas, 1919. (From the Company.)

American Blower Company, Bulletin No. 19. Detroit, Mich., 1919. (From the Company.)

American Society for Testing Materials, Membership List. Philadelphia, Pa., 1919. (From the Society.)

L'Année Scientifique et Industrielle, 1908. Paris, 1909. (From Mr. W. G. Button.)

Appleton Electric Company, Catalogue No. 8. Chicago, Ill, 1918. (From the Company.)

Badger, E. B., and Sons Company, Bulletin No. 100. Boston, Mass., 1919. (From the Company.)

Bausch and Lomb Optical Company, Catalogue of Optical Glass. Rochester, N. Y., 1919. (From the Company.)

Canada Department of Mines Summary Report, 1918, Parts C, D, F, G. Ottawa, Canada, 1919. (From the Department.)

Channon H. Company, Catalogue No. 80. Chicago, Ill., 1916. (From the Company.)

Chemie der menschlichen Nahrungs-und Genussmittel. By Dr. J. Koenig, two vols. Berlin, Germany, 1879–1880. (From Mr. Reuben Haines.)

Clayton and Lambert Manufacturing Company, Bulletin No. 4. Detroit, Mich, no date. (From the Company.)

Clow, James B., and Sons, Booklet of Water Sterilization. Chicago, Ill., 1919. (From the Company.)

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Colorado Bureau of Mines, Bulletin No. 8. Denver, Col., 1919. (From the Bureau.)

Columbia University, Publication No. 8. New York, N. Y., 1919. (From the University.)

Condit Electrical Manufacturing Company, Catalogue No. 125. Boston, Mass., no date. (From the Company.)

Davis-Boutnonville Company, Catalogue of the Pyrograph. Jersey City, N. J., 1919. (From the Company.)

Economy Electric Devices Company, Bulletins Nos. 50 and 60. Chicago, Ill., no date. (From the Company.)

General Chemical Company, Bulletin No. 3. New York, N. Y., no date. (From the Company.)

George Washington University, Catalogue No. 2. Washington, D. C., 1919. (From the University.)

Gilfillan Brothers Smelting and Refining Company, Catalogue of Gilfillan Products. Los Angeles, Calif., 1919. (From the Company.)

Hamilton Association, Journal and Proceedings. Hamilton, Canada, 1919. (From the Association.)

Hendrie and Bolthoff Manufacturing and Supply Co., Catalogue No. 50. Denver, Col., 1919. (From the Company.)

Hornung, J. C., Bulletin No. 14. Chicago, Ill., 1919. (From J. C. Hornung.)

How the Nitrogen Problem Has Been Solved. By Henry Jermain Maude Creighton. Philadelphia, Pa., 1919. (From the Author.)

Instituo y Observatorio de Marina, Anales 1916–1917. San Fernando, 1917–1918. (From the Institute.)

Kansas Board of Agriculture, Report for the Quarter ending March, 1919. Topeka, Kan., 1919. (From the Board.)

Lehrbuch der Organischen Chemie. By Dr. E. F. v. Gorup-Besanez, three vols. Braunschweig, 1873–1874. (From Mr. Reuben Haines.)

Locke Insulator Manufacturing Company, The Insulator Book. Victor, N. Y., 1919. (From the Company.)

Los Angeles Pressed Brick Company, Catalogue of Roofing Tiles. Los Angeles, Calif., 1919. (From the Company.)

McCool Company, Bulletin No. 49. Cleveland, Ohio, 1919. (From the Company.)

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Manufacturers' Aircraft Association, Year-Book, 1919. New York, N. Y., 1919. (From the Association.)

Massachusetts Board of Gas and Electric Light Commissioners, Thirty-fourth Annual Report, 1918. Boston, 1919. (From the Board.)

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Monighan Machine Company, Catalogue No. 19. Chicago, Ill., 1919. (From the Company.)

Nelson Valve Company, Catalogue No. 10. Philadelphia, Pa., 1919. (From the Company.)

New York City Board of Water Supply, Thirteenth Annual Report, 1919. New York, 1919. (From the Board.)

North Western Expanded Metal Company, Handbook of Fire-proof Construction. Chicago, Ill., no date. (From the Company.)

Ohio Blower Company, Catalogue No. 22. Cleveland, Ohio, 1919. (From the Company.)

Ohio Brass Company, Catalogue No. 17. Mansfield, Ohio, 1919. (From the Company.)

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O. K. Clutch and Machinery Company, Catalogue No. 19. Columbia, Pa., no date. (From the Company.)

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Smithsonian Institution, Publication No. 2493. Washington, D. C., 1918. (From the Institution.)

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Southern Railway Company, Twenty-fifth Annual Report, 1918. Richmond, Va., 1919. (From the Company.)

St. Louis Water Commissioner, Annual Report for Year ending April 1, 1919. St. Louis, Mo., 1919. (From the Commissioner.)

Stimpson Equipment Company, Catalogue of the Mitchell Electric Vibrating Machine. Salt Lake City, Utah, no date. (From the Company.)

Stow Manufacturing Company, Inc., Bulletin No. 103. Binghamton, N. Y., 1919. (From the Company.)

Strong, Carlisle and Hammond Company, Catalogue of Strong Steam Specialties. Cleveland, Ohio, no date. (From the Company.)

Sturtevant, B. F., Company, Catalogue No. 255. Hyde Park, Mass., 1919. (From the Company.)

Superheater and Engineering Company, Catalogue of Dravo Superheaters. New York City, N. Y., 1919. (From the Company.)

Tasmania Geological Survey, Bulletin No. 29. Hobart, 1919. (From the Survey.)

Thacher Propeller and Foundry Corporation, Catalogue M. Albany, N. Y., 1919. (From the Company.)

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Watuppa Water Board, Forty-fifth Annual Report. Fall River, Mass., 1919. (From the Board.)

Wellman-Seaver-Morgan Company, Bulletin No. 34. Cleveland, Ohio, 1919. (From the Company.)

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Wetzel Mechanical Stoker Company, Catalogue No. 9. Trenton, N. J., 1919. (From the Company.)

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U. S. Bureau of Mines: Monthly Statement of Coal-Mine Fatalities in the United States, August, 1919, compiled by Albert H. Fay. 20 pages, 8vo. Technical Paper 210. An Analytical Method for Detecting Blown-out Shots in Coal Mines, by G. F. Hutchison and Jacob Barab. 22 pages, 8vo. Technical Paper 231. Production of Explosives in the United States During the Calendar Year 1918, compiled by Albert H. Fay. 21 pages, 8vo. Technical Paper 234. Sensitiveness of Explosives to Frictional Impact, by S. P. Howell. 17 pages, 8vo. Technical Paper 236. Abatement of Corrosion in Central

Heating Systems, by F. N. Speller. 12 pages, 8vo. Technical Paper 237. Safe Practice in Using Wire Ropes in Mines, by R. H. Kudlich and O. P. Hood. 11 pages, 8vo. Technical Paper 242. Why and How Coke Should be Used for Domestic Heating, by Henry Kreisinger and A. C. Freedner. 20 pages, 8vo. Washington, Government Printing Office, 1919.

Library News: Semi-Monthly Bulletin of the Engineer School Library issued at Camp A. A. Humphreys, Va. Vol II, Nos. 11–14, June and July, 1919. 8vo.

Melting Point of Refractory Materials. LEO I. DANA. (*Bull. Am. Inst. Mining and Metallurgical Engineers,* September, 1919.)—As refractory substances are usually not pure crystalline materials, their change from the solid to the liquid state is not sharply marked as in the case of ice, but is a gradual process, and extends through a range of temperature. Sintering or vitrification is the first stage on the road to liquefaction. Circumstances which affect the apparent melting point are:

(*a*) Time during which the refractory is kept at a temperature producing vitrifaction. The longer the time the more complete is the sintering and other physical and chemical results. Lengthening the time increases fusibility.

(*b*) Rate of heating. In general the more rapidly the temperature rises the higher the melting point seems to be.

(*c*) Nature of surrounding atmosphere. This may enter into chemical combination with the refractory substance or may influence volatilization.

(*d*) Substances in contact with the refractory, such as slags, fluxes and flue dust.

(*e*) The load applied.

The influence of these last factors is so complex that at present it is impossible in general to predict what effect will be produced on the melting point by varying them.

G. F. S.

Spraying Metals. (*Electrician,* vol. lxxxiii, September 19, 1919, p. 302.)—Schoop's process of spraying metals is being further developed. Two wires of the metal are connected to the terminals of the electric circuit, then touched and separated to form an arc. This fuses part of the wires which are fed forward continuously. An air blast projects the molten metal in finely divided form upon any desired object. Glass, celluloid, paper, etc., are thus given a metallic coating. Glass plates so prepared are used for electrical condensers. The process is employed also to secure good metallic contact, and to facilitate soldering. Electric heaters are made by spraying metal on refractory substances.

G. F. S.

CURRENT TOPICS.

Optical Glass and Chemical Glassware. (*U. S. Tariff Commission Information Bulletin*).—Of the many industries that have been developed in this country by the necessities of the war, few, if any, have had such brilliant success as the manufacture of glass for scientific purposes. The lack of supply for these purposes began to be felt as soon as the British blockade became effective, and by 1917 the attention of American scientists and officials had been strongly directed to the problem of home manufacture. Optical glass has for many years been imported, principally from Germany, but some from France and England. It was not made in the United States. Rough or unwrought optical glass has been for years on the free list. At the present time through the large experience and organization developed by the necessities of the case, the optical glass industry in the United States has the scientific knowledge, materials, and equipment to compete in regard to quality of product with the best of foreign manufacture. Still the whole demands of the market are not met, for in 1918 we were obliged to import about one-half the normal amounts of unwrought glass and in addition large amounts in the form of optical instruments. Scientific authority informs us that four kinds of optical glass are the most needed: A very light and transparent crown, an ordinary crown of higher index, a typical heavy flint and a typical light flint. Next to these most important forms, are a heavy barium crown and a light barium flint especially used in photographic apparatus. The further development of these industries cannot be expected if such products are kept on the free list or subjected to merely nominal duties, and moreover, the present condition by which all educational institutions are permitted to import even complete optical instruments free of duty, will seriously interfere. Glass makers are asking for the repeal of this clause, a request which has met with a good deal of approval from the scientific workers of the country.

Chemical glassware, generally known in the trade as "hollow ware" is used in enormous amounts in the United States, and has been for many years almost entirely supplied by Germany and Austria, the several brands being among the most familiar titles in the laboratory. This supply also being shut off, the attention of American glass-makers was directed to finding substitutes, and here, as in the case of the optical glass, great success has been achieved. Indeed, it is now generally admitted that much of the American glass is better than any that has heretofore been

obtainable from abroad. Factory-blown ware of this high quality is now being made in seven American factories that were in active operation for ordinary glass-making before the war. These manufacturers express confidence that they can maintain their industries without increase of the present duty of 45 per cent. ad valorem, but ask that the duty-free clause applicable to scientific institutions which are very large users of these forms of glass-ware owing to the students laboratories, be repealed and that all chemical glass-ware be made dutiable at the 45 per cent. rate. Here again, the expressions of chemists and officers of scientific institutions are largely favorable to the repeal. Statistics show that before the war the duty free importations amounted to about half of the value of the total imports based on the invoices.

The Bureau of Standards has made thorough examinations of the American ware in comparison with the best foreign ware, and reports that all the former are superior to the Kavalier ware and equal or superior to the Jena ware for general laboratory use.

H. L.

Utilization of Nitre-Cake. GILBERT T. MORGAN. (*Economic Proceedings, Royal Dublin Society,* vol. ii, p. 238, 1919.)—Nitre-cake is the residue of the action of sulphuric acid upon sodium nitrate, and consists mainly of sodium acid sulphate. During the war British munition industries produced enormous quantities of this material, one factory alone having an output of over 200 tons per week, much of which was dumped into the sea. When the output was much smaller, as in peace-times, the material was utilized for the manufacture of salt-cake and hydrochloric acid, the former being employed in the Leblanc process for sodium carbonate. Some of the nitre-cake was converted into sodium sulphide, which is now used as a reducing agent in organic syntheses.

Morgan sought for some methods which would utilize the sulphur as well as the sodium. He reviews the methods already known, and then describes a procedure devised by himself in which the cake is used for the production of soda-lime and soda-lead glasses at one operation with recovery of the sulphur, either free or as sulphuric acid. It will suffice to describe briefly one of these procedures.

Seventy-two grammes of nitre-cake, 100 grammes of sand, 20 grammes of limestone, and 4 grammes of wood charcoal, were heated in a fire-clay retort connected with a model of a leaden chamber. The fixed product was clear green glass, the volatile products were sulphuric acid, sulphur dioxide, and free sulphur. The heating was continued for twelve hours, but the bulk of the volatile products was evolved in the first two hours. The volatile products were then mixed with steam, air, and nitrous fumes for oxidation. The analytical figures show that over half the sulphur can be recovered either as sulphuric acid or as the free element.

H. L.

Water Power of France. (*Bull. Am. Inst. Mining and Metallurgical Engineers,* September, 1919.)—In the Alpine region drained by the Rhone and its tributaries 6,000,000 horsepower can be developed at average water flow. Elsewhere in France 3,000,000 horsepower additional may be obtained from streams. These numbers should be divided by two to get the output for low-water flow. At the close of 1915, 738,000 horsepower was obtainable from installations in the Alps. This amount has been much increased since that time. G. F. S.

Depreciation in Small Dry Cells with Age. A. J. HELFRECHT. (*American Electrochemical Society,* 1919.)—The author endeavors to show how closely the method of judging cell deterioration, called "flash test," approaches actual measurements of capacity through discharging the cells. Comparative curves for the different sizes of cells tested are given. From the data gained by this investigation a table has been compiled indicating reasonable depreciation of the four important sizes of small cells.

The Effect of Amalgamation Upon the Single Potential of Aluminum. LOUIS KAHLENBERG and JOHN A. MONTGOMERY. (*American Electrochemical Society,* 1919.)—Measuring the single potential of aluminum in a one-third molar solution of aluminum chloride at room temperature, by means of the calomel electrode, the writers obtained much higher values with amalgamated than with unamalgamated aluminum, due to the removal of the coat of resistant oxide by the mercury. They showed also that the measurements were actually the single potentials of the aluminum and not those of an aluminum amalgam.

Invisible Light in Warfare. R. W. WOOD. (*Proceedings of the Physical Society of London,* vol. xxxi, p. 232, 1919.)—When a source of light is put at the principal focus of a converging lens the emergent beam consists of parallel rays and consequently does not change in cross-section as it proceeds. Often the narrowness of such a beam prevents its being observed. Greater accuracy was obtained by using a filter which permitted only the extreme red rays to issue. These would be invisible to an observer unless he protected his eyes from daylight by a similar screen. Through such a screen only the red light could penetrate and the eyes of the observer would be in a sensitive state owing to the exclusion of ordinary light. By such an arrangement secret signals can be transmitted. A variation of method was the use of a screen transmitting only ultra-violet light, which was received on a fluorescent screen. The range of signalling in both cases was about six miles.

The following arrangement proved of great value in maintaining communication between ships of the same convoy at night. In this case the light was sent out not as a parallel beam, but as a

beam diverging in all directions. A Cooper-Hewitt mercury arc was the light source. It was surrounded by a glass chimney through which only ultra-violet light emerged. This caused parts of the eye and natural teeth to fluoresce, while false teeth were black. The receiving apparatus is a barium-platino-cyanide screen placed in the principal focus of a converging lens. The range was about four miles. G. F. S.

Location of Aeroplanes by Wireless Telegraphy. J. ROBINSON. (*Nature*, September 11, 1919.)—Dead reckoning methods are of little use for such a purpose owing to the pilot's ignorance of the velocity of the air with respect to the earth. A loop of wire exposed to electrical waves has an E.M.F. developed in it which varies in strength according to the relation of the plane of the loop to the direction in which the waves are travelling. By changing this spatial relation and by noting the effect upon the current induced in the loop it is possible to find the location of the aeroplane. The Germans did this by sending waves out from the aircraft and by receiving them on loops at various places on the ground. Observers at a central station worked out the position of the source of the waves and sent the information to the aeroplane.

The Royal Air Force solved the problem by having a loop on the aeroplane receive waves from several stations. The bearing of each station was worked out by the aerial observer and from this he worked out his position. As wireless signals are noted by the ear, difficulty was found in applying this method owing to the noises of the wind and of the engine. This obstacle was overcome by increasing the strength of the signals. Electrical disturbances emanating from the magneto were avoided by shielding the machine.

Two loops, main and auxiliary, with planes at right angles to each other were mounted on the aeroplane. When the loops have this relative position one has its maximum current when the other has its minimum. Suppose the main loop is turned until its current is a maximum and that then the auxiliary loop is joined to the main one. A little later the auxiliary loop is joined in the reversed direction. As this loop had no current, reversing it makes no difference. If, however, the main loop was not accurately in the position for maximum current, the auxiliary loop would have a current in it and reversing it would make a difference. The procedure is to rotate the main loop until its position for maximum current is approximately found. Then the auxiliary coil, always at right angles to the other, is introduced into the circuit first in one direction and then in the other, and the two loops are rotated about their common axis until no change in the intensity of the signals is caused by reversing the auxiliary loop. Then the position of the plane of the main loop to the direction of propagation of the waves is known.

The two loops may be mounted on the framework of the aeroplane, in which case the whole plane must be swung to vary their direction, or they may be supported by a mounting attached to the fuselage so that they may be turned independently of the plane.

The German method of calculation performed on the ground is the more accurate, since it gives the position of the aeroplane within two miles, while the other method, largely owing to compass errors, has an error of seven miles. Nevertheless, long flights have been made by the use of the latter method, *e.g.*, from a town near London to Paris and back to England. The navigator was able to forecast the time of his arrival within two minutes.

G. F. S.

The British Fleet During the War. SIR E. T. D'EYNCOURT, K.C.B. (*Institution of Naval Architects*, April 7, 1919, through *Journal of the American Society of Naval Engineers*, May, 1919.)—During the war the additions to the British fleet amounted to 2,000,000 tons at a cost of £250,000,000. Great efforts were made to finish the vessels already under way. Only such others were ordered as could be designed and completed in a short time. Belief in a brief war modified the naval program. As soon as the submarine menace was recognized, orders were placed for patrol boats, torpedo-boat destroyers, submarines, light cruisers, sloops, mine sweepers, etc. Many such were satisfactorily constructed by firms hitherto engaged only in commercial work.

The experience acquired in the battle of Jutland led to the application of additional protection to the magazines of battleships. The value of the longitudinal, protective bulkhead with the accompanying subdivisions was demonstrated when the post-dreadnaught *Marlborough* was torpedoed and yet was able to keep in line. She was safely docked in the Tyne. The decision to increase the speed of the battleships of the Queen Elizabeth class from 21 to 25 knots necessitated the doubling of the horsepower. This class had oil as the sole fuel with oil bunkers 30 feet high, especially designed to withstand the pressure of the contained liquid. Oil fuel was a distinct success as it was found easier to maintain a high speed continuously by its use. Of course, a smaller number of men were needed than with coal.

The shaft horsepower of the battle-cruisers reached 112,000 in the case of the *Renown* class with a displacement of 26,500 tons and speed of almost 32 knots. Two vessels of this classs had their commissioning trials a trifle more than eighteen months after the date of the first order to get out their design.

Three hundred torpedo-boat destroyers and flotilla leaders as well as 100 mine sweepers were added to the British fleet. "China" gunboats, 120 feet long, were constructed in Great Britain and sent out in parts to be assembled at Abadan. Twelve types of submarines were made, among which was one employing steam tur-

bines for the surface, by which a speed of 24 knots was obtained. The problem of caring for the funnels was successfully solved. These vessels had electric drive while under water, and a Diesel engine to use in the act of submerging or of emerging. The claim is made that the British produced submarines with greater speed on the surface and also under water than the Huns had, as well as more heavily armored craft. One monitor submarine carried a twelve-inch gun.

Among auxiliary craft are fast fleet oilers, carrying 5000 tons of oil, speed 15 knots. Aircraft carriers were made from merchant ships. Of these the *Argus* had flush decks and long horizontal ducts to discharge the smoke astern. G. F. S.

Potash from Kelp. J. W. TURRENTINE and PAUL S. SHOAFF describe the experimental plant of the U. S. Department of Agriculture at Summerland, California. (*Journal of Industrial and Engineering Chemistry,* vol. xi, pp. 864–874, 1919.)—Kelp is collected by boats of 100 to 150 tons capacity, provided with twin screws and driven by internal combustion engines. The extreme bow of the boat is provided with the harvesting apparatus, the kelp is cut by means of knives approximately four feet below the surface of the water, and is then carried to the deck by a conveyor, from 25 to 50 tons are harvested in an hour. The cargo is removed from the boat by an automatic fork which delivers its load to the hopper of a chopper on the dock. The chopper cuts the kelp into lengths of approximately 6 feet, which are then moved to the storage bin of the plant by drag conveyors. The raw kelp is fed into a rotary drying kiln, where it meets a counter current of hot air, which enters the kiln at a temperature of 800° C. and leaves it at a temperature of 50° C. This preliminary drying is followed by a final drying in a similar kiln. The dried kelp is fed into the top of a retort, which is kept at a temperature of approximately 980° C. The charred mass is drawn off from a hopper at the bottom of a retort, cooled, ground and lixiviated. The by-products are recovered.

In the lixiviation use is made of leaching troughs, filter presses, and the principle of the counter current. The char is first extracted with a concentrated brine, while fresh hot water is used for its final extraction. The press coke of charcoal is extracted successively with hot hydrochloric acid and water, by proper extraction, a product is obtained which is of value as a decolorizing agent for certain organic liquids and aqueous solutions. The charcoal is then collected in a filter press and dried.

After removal of sulphates, the brine from the leaching process is heated in a vacuum pan until a definite concentration is reached, it is then transferred to a vacuum crystallizer, where the potassium chloride deposits. The cooled brine is returned to the vacuum pan and further concentrated while sodium chloride separates. Each salt is washed, dried first in a centrifugal ma-

chine, then in a rotary, counter-current, hot-air drier, and finally packed for market. The mother liquors are used until their content of iodine salts has become sufficiently great. They are then treated for the recovery of iodine as a by-product.

The volatile by-products recovered from retorting include ammonia liquor, methyl alcohol, and an oily distillate from which have been obtained an oil which is of value in the concentration of ores by flotation, and a creosote which is highly toxic to bacteria and may be used as a wood preservative. Gas is also produced in the retort and is used as fuel.

By another process, the dried kelp is fed into one end of a rotary kiln while a flame from burning oil enters at the other end; the kiln is lined with fire brick. Charcoal is produced and leaves the kiln at a low red heat; it may be quenched, ground, and leached to obtain the potash salts, or it may be permitted to burn to a loose, gray, non-caking kelp ash with a potassium content equal to approximately 35 per cent. K_2O.

Manufacture of War Gases in Germany. JAMES F. NORRIS. (*Journal of Industrial and Engineering Chemistry,* vol. xi, pp. 817–829.)—This paper by Lieutenant-Colonel Norris is based on his official tour of inspection of chemical plants at Leverkusen, Höchst am Main, Biebrich, and Ludwigshafen in the occupied zone of Germany. In addition to the manufacture of poison gases, attention is also paid to the manufacture of synthetic rubber and of charcoal for gas masks.

Rubber was manufactured from acetone. This compound was reduced to pinacone by means of aluminum and hydroxide. The pinacone was distilled under pressure; it thereby lost water from its molecule, and yielded a distillate of methyl butadiene, an unsaturated hydrocarbon. Polymerization was produced by heating this hydrocarbon at a temperature of approximately 600° C. for a period of 4 to 6 months; the product of methyl rubber was a clear, tough, white, transparent mass, with the properties of the best caoutchouc, and was used in the manufacture of automobile tires and other rubber goods.

Charcoal for gas masks was made from pieces of wood (usually pine) of even size and one-fourth inch in diameter. They were soaked for at least 30 minutes in hydrochloric acid of 20° to 40° Baume, to which a small, but indefinite amount of zinc chloride had been added. They were then packed into a muffle, which was 24 inches square by 12 feet long, until only a few inches of air space remained above the pile of wood. The muffle was provided with an iron door, a lining of porcelain tile and a stoneware flue pipe, which led to an hydrochloric acid condenser plant. Carbonization occurred slowly and very thoroughly; the muffle was heated to a cherry red, and heat was applied for at least 6 or 8 hours. The charcoal was washed with hydrochloric acid until the soluble

ash had been reduced to a minimum, and the finished product contained approximately 0.01 per cent. of zinc. It was next washed free from acid. The total time required for washing was 2 or 3 days. The charcoal was then drained on a grill, dried in vacuum at 70° to 80° C., and finally sifted in a rotary sieve to remove the dust.

The processes used in the manufacture of the various poison gases may be briefly outlined.

Mustard gas, or B_1B' dichlorethyl sulphide, was manufactured from common grain alcohol. Ethylene was obtained by passing alcohol vapor over aluminum oxide at a temperature of 380° to 400° C. Ethylene chlorhydrin was prepared by passing carbon dioxide and ethylene into an aqueous solution of chloride of lime. By reaction with sodium sulphate, the chlorhydrin was changed to B_1B' dihydroxy ethyl sulphide; this compound was converted into mustard gas by treatment with hydrogen chloride. The mustard gas was used as a solution in either chlorbenzene or carbon tetrachloride.

Perchlormethyl formate, also called trichlormethyl chlorformate, diphosgene, or superpalite, was manufactured by two processes. Methyl formate was made in the usual way, then chlorinated under the influence of high candle power lights with osram filaments. Or methyl chlorformate was prepared by the reaction of phosgene (carbonyl chloride) and methyl alcohol, and was then chlorinated.

The raw materials for the manufacture of diphenylchlorarsine or blue cross gas were aniline and arsenous oxide. The diazotized aniline hydrochloride was permitted to react with sodium arsenite in the presence of cupric sulphate to obtain the sodium salt of phenylarsenic acid. This acid was liberated by addition of hydrochloric acid, then reduced to phenylarsenous acid by use of sulphur dioxide. The sodium salt of phenylarsenous acid was next condensed with diazabenzene chloride to obtain sodium diphenylarsenate, which yielded diphenylarsenic acid when treated with hydrochloric acid. The diphenylarsenic acid was reduced to diphenylarsenous oxide by means of sulphur dioxide. This oxide was immediately converted into diphenylchlorarsine by hydrochloric acid, which had been added to the reaction mixture.

Diphenylcyanarsine was made by treating diphenylchlorarsine with either sodium cyanide or potassium cyanide.

In the manufacture of ethyldichlorarsine, ethyl chloride was made to react with sodium arsenite to obtain sodium ethylarsenate. The solution of this salt was made neutral, treated with an excess of sulphur dioxide, and heated to 70° C. The ethylarsenic acid was reduced to ethylarsenous acid, then converted into the anhydride of the latter, *i.e.*, ethylarsenous oxide. This oxide was changed into ethyldichlorarsine by treatment with hydrogen chloride.

Phenyliminophosgene was made by the action of chlorine on phenyl mustard oil.

Symmetric dichlor methyl ether was obtained by the action of chlorsulphonic acid on either paraformaldehyde or an aqueous solution of formaldehyde in the presence of sulphuric acid and water. Symmetric dibrom ethyl ether was manufactured in exactly the same manner except that ammonium bromide was substituted for chlorsulphonic acid.

Bromacetone and brommethylethyl ketone were made from acetone and methylethyl ketone respectively by treatment with bromine and chlorate of either sodium or potassium in aqueous solution.

Xylyl bromide was prepared by bromination of xylene, chlorpicrin by the reaction of picric acid and bleaching powder.

Phosgene was obtained by the union of carbon monoxide and chlorine in the presence of a carbon catalyst, which was prepared from wood charcoal by treating with hydrochloric and other acids until entirely free from soluble ash, washing, and drying in vacuum. Animal charcoal yielded an even better catalyst. The charcoal was used in fragments of approximately one-fourth inch mesh, and retained its catalytic activity for about six months. The carbon monoxide was prepared by passing carbon dioxide over charcoal in gas-fired muffles and washing with sodium hydroxide.

The average monthly production in tons, of certain of these poison gases was:

Mustard gas	300
Diphosgene	439
Diphenylchlorarsine	150
Ethyldichlorarsine	78
Phosgene	318
Phenyliminophosgene	65
Dichlormethyl ether	26
Dibrom methyl ether	7
Chlorpicrin	245
Xylyl bromide	55
Bromacetone plus Brommethyethyl ketone	19

J. S. H.

Solar Constant of Radiation. C. G. ABBOTT. (*Proc. National Academy of Sciences,* September, 1919.)—The quantity of energy from the sun, incident in one minute upon one square centimetre of surface, at mean distance from the sun, outside the earth's atmosphere and placed perpendicular to the direction in which the radiation moves, is called the Solar Constant of Radiation. For fourteen years the Smithsonian Astrophysical Observatory at Mount Wilson, Calif., has been studying this constant. One result is that it turns out to be no constant at all. From day to day it changes, proving the sun to be a variable star. There are two super-imposed variations, one with a range of from 3 per cent.

to 5 per cent., extending over the period of the sun-spot cycle, the other being irregular and having periods of months or days with a range of occasionally as much as 10 per cent.

Observations in Algeria in 1911 and 1912 confirmed the Californian results. Since 1918 an expedition has been measuring the constant in Chile, at an altitdue of 7500 feet, in a very cloudless region. It is found that at Mount Wilson and at Calama, Chile, in different hemispheres and 5000 miles apart changes in the quantity of radiation received from the sun keep step with each other. Furthermore, a connection has been established between variations in solar radiation and weather conditions on the earth. The Argentine government is employing radiation data from Calama in forecasting the weather.

Observations at both stations showed that the solar radiation was greater than the average in 1918, equalling 1.95 calories per minute. The average value is 1.93. G. F. S.

Alcohol as a Motor Fuel.—Reference was made recently in a note in this JOURNAL to the importance of investigations for securing cheap methods of production of alcohol suitable for use in internal combustion engines. The supply of petroleum products, while abundant, is not inexhaustible, and as alcohol is obtainable from vegetable substances, there is no practical limit to the supply. At present, the cost of production is the only serious bar to its extensive use. The use of gasoline is increasing at a rapid rate. The following figures taken from an article in *The Engineer* (1919, vol. cxxviii, p. 17) show in round numbers the consumption of gasoline in the United States for the past few years:

Year	U. S. Gallons	Increase
1914	1,440,000,000	
1915	1,680,000,000	240,000,000
1916	2,000,000,000	320,000,000
1917	2,780,000,000	780,000,000
1918	3,210,000,000	430,000,000

The reduction in the rate of increase from 1917 to 1918 is doubtless due to the restriction of private use under the government appeals, as in the case of the "gasless Sundays." It is almost certain that 1919 will show a great increase over 1917.

Influenced by the importance of the problem and by the fact that Great Britain must obtain a large part of its gasoline or other hydrocarbon fuel from other countries, the British government appointed a commission to investigate the alcohol question. The report of this commission has just been published. Some of the data are given in the issue of *The Engineer* above quoted.

It is pointed out that not only will the demand for ordinary motor cars, pleasure or commercial, be constantly increasing, but

the development of the airplane and dirigible will add enormously to the requirements. If alcohol can be substituted in large part for the other hydrocarbon fuels it will be possible to establish stations for its manufacture at or very near to the stations of the air lines, thus materially diminishing the expense of handling the fuel.

It is stated that a great deal of molasses goes to waste, which might be utilized as a source of alcohol. One ton of potatoes (2240 pounds) yields 24 (U. S.) gallons of 95 per cent. alcohol. Peat has not yet been successfully used. Reference is made to a tree that grows in the central India region, the flowers of which contain considerable amount of fermentable sugar. According to the report, the sun-dried flowers contain 60 per cent. of this, and ought to yield somewhat over 100 (U. S.) gallons per long ton. It does not seem likely, however, that a tree flower could be obtained in sufficient abundance to affect materially the supply of alcohol.

The commission recommends a search for cheap denaturants or those which are effective in very small amount (suggesting formaldehyde as one of the latter) and points out that much of the strictness of the revenue laws will have to be relaxed if a cheap fuel is to be obtained. It also recommends that all industrial alcohol should be sold with indication of its percentage of ethyl hydroxide. One advantage of alcohol as a fuel is that it will be practically uniform in efficiency wherever obtained.

H. L.

Analysis of Photographs of Fog Signals Obtained with the Phonodeik. D. C. MILLER. (*Trans. Royal Society of Canada*, March, 1919.)—The source of the signals was a Northey diaphone at Father Point Station, Quebec. Photographs were made by the phonodeik, one of Professor Miller's own devices. A horn directs the sound waves upon a sensitive diaphragm whose vibrations are transmitted to a small mirror. A beam of light is reflected from this and falls on a moving photographic film. As the mirror vibrates the reflected beam moves correspondingly and a sinuous trace of the sound wave is produced on the film.

Records were taken at different distances over water in front of the fog-signal and also on the land away from the axis. By means of the apparatus described in the JOURNAL OF THE FRANKLIN INSTITUTE, January and September, 1916, the curves were analyzed into twenty or even thirty components and the results of the analysis were proved by synthesis. The effective frequency of the fog-signal was 174 per second, though a note an octave below was always present. The analysis gives the amplitude of this lowest component and of 19 harmonics. When these were combined they reproduced the curve actually photographed by the phonodeik.

The relation between the amplitudes of the several overtones

varies greatly, changing with distance from the source. The higher harmonics are always feebler than the lower group and disappear entirely at about two miles from the signal. A study of the intensities of the harmonics shows that the master-tone, 174 in frequency, carries best of all to distances of two miles or more, though the octave above it exceeds it at 1100 feet nearer the source. The inverse square law of decrease of intensity was found to be invalid.

When a horn was used on the fog-signal and photographs taken away from the axis, the higher harmonics were not relatively so strong as they were along the axis. An increase in the air pressure used in blowing the diaphone resulted in an increased acoustical output. Elevating the air pressure caused those tones which had the greatest carrying power to increase in intensity more rapidly than the others. G. F. S.

French Railways, Highways and Canals After the Invasion by the Huns. (*Genie Civile*, April 5 and September 27, 1919.)—In a report made to the President of France, March 21, 1919, it is stated that the following losses were inflicted upon the railroads of France during the war: 5600 km. of single track line, 1510 bridges, 12 tunnels and 590 buildings. To render the tracks useless the Huns employed a crude but effective plow of rails dragged along the road-bed by a locomotive. Some hundreds of mines calculated to explode after a long interval were left in place. The seriousness of the situation was shown by the fact that of the seven lines formerly connecting Paris to Alsace-Lorraine only one was left in operating condition. Fifty thousand freight cars were lost by France in August, 1914. At the beginning of the present year great numbers of locomotives, freight cars and passenger cars were awaiting repair. Highways. One hundred and five thousand kilometres of roads were in need of more or less considerable repair. Canals. The work of destruction embraced 450 bridges, 115 locks and 1075 km. of canals or canalized rivers.

The later number of *Genie Civile* renders due credit to the assistance of the British and the American troops and presents an encouraging report of the state of the repair work. In the railroad systems of the north by September 1, 1919, all of the single track lines and all but 6 km. of the double track lines have been restored. Only four (4) of the destroyed stations remain to be cleared away, one viaduct has been put anew in service and others were nearing completion. In the system of the east more remained to be done.

The canal system has been restored to a surprising extent. Paris is again connected to the coal fields of the north by internal water-ways, and also with the east. Electric traction to transport the coal from the Sarre basin is to be installed on the Marne-Rhine Canal.

Much work has been done in road repair. Bridges amounting in length to a total of 4 km. have been put in position. Seven thousand kilometres of roads have been restored, but much repairing awaits the future. G. F. S.

Safety in a Steel Plant. H. P. HEYNE. (*National Safety Council,* 1919.)—Each establishment should have its system of shop discipline, but there are ways in which the emplyees can better inform themselves regarding what is expected of them, through the inauguration of a systematic program for conducting the work.

The new way to put safety across in any plant, is to meet the problems with a better understanding of affairs, and an assurance of fairness between the foremen and the employees, which should furnish the material for erecting the foundation for the coöperative spirit which the coming era is ushering in.

The two factors which bind men together are fellowship and good-will, based on mutual confidence. These are indispensable in attaining unity of purpose on the part of all for the welfare of all. A. R.

Further Notes on Alcohol as Fuel. (*Bulletin 245, Am. Chem. Soc. News Service.*)—King Alcohol was hailed as a new monarch of the realm of power in a symposium held Friday, October 10, by the New York Section of the American Chemical Society. The five well-known chemists who addressed the section told of new sources of alcohol which could be tapped and indicated many new uses for it.

B. R. Tunison said that probably ten times as much alcohol as was consumed before Prohibition days would eventually be utilized by the American people, albeit, they have decided to dispense with it as a beverage. In a normal year the United States drank 160,000,000 gallons of alcohol and used approximately 100,000,000 gallons in the various arts. Among the sources which could be developed is the nipa palm which flourishes in the Philippines and other tropical countries, and yields, said Mr. Tunison, about 15 per cent. of sugar which could be fermented. From that source alone 50,000,000 gallons a year could easily be produced. The Mexicans brew a fiery beer from the sotol plant, a variety of agave which exists in very large quantities in their country from which millions of gallons could be distilled. By changing the cellulose of sawdust and other wood waste into sugar and then fermenting that substance, plenty more alcohol can be obtained. It is identical with that derived from grain and is quite different from the methyl or so-called wood alcohol of the "Pink Elephant" brand which is made by another process. Considerable alcohol can also be derived from the waste of gas works.

In order to bring all these alcohols within the domain of the law they have been denatured or treated in such a way as to make them unfit for human consumption. There are now about forty denaturing formulas which are approved by the Internal Revenue Bureau. The Government puts on a tax of $4.15 a gallon on straight alcohol even if employed for industrial purposes. Undrinkable alcohols are used as solvents in the various chemical industries and especially in the development of the rapidly growing dye-industry. They can serve well in the manufacture of rosins as a solvent and by their use a perfectly transparent product can be manufactured.

Mr. Tunison prophesied that as the petroleum supply decreases and the price of gasoline is therefore raised, alcohol will come into greater use as a motor fuel. Denatured ethyl alcohol, identical in composition with that distilled from grains, is now cheap in car-load lots, and there are compounds of it which are sold even now for only a few cents more a gallon retail than the price of gasoline. Mr. Tunison said that these new alcohol fuels yield more power to the gallon than does gasoline and do not clog carburetors. There is also a demand for the so-called solidified alcohol which is made by adding paraffine and such substances to spirits.

F. W. Kressmann gave details concerning the manufacture of "Ethyl Alcohol from Wood Waste." G. F. Richmond told of the possible increased use of the so-called "Higher Alcohols" which are employed in the manufacture of extracts and perfumes. Ralph H. McKee spoke of "Alcohol from Sulphite Wood Waste," and Leonard H. Cretcher's topic was "The Use of Alcohol in the Dye Industry."

Tanks in Warfare. (*Society of Automotive Engineers,* 1919.)—There is no doubt of the great value of tanks in warfare. They are an answer to the machine gun. As in other automotive vehicle design the questions which arise in formulating specifications for tanks relate to overall size, amount of internal space, power, capacity and running speed. There are, of course, numerous other matters involved by virtue of the characteristics of tank operation, such as balance and ground pressure. The power plant is obviously a vital feature of the tank. The tank now has one-man operation as a feature, whereas several men were required to drive the first European models. Generally speaking, it is to be expected that tanks and tractors will not only be equipped with various types of accessories developed and to be developed, but be lighter, faster and less noisy. One interesting phase of tank construction is the feasible life of the machine under strenuous conditions so far as the power plant is concerned. There is no doubt that the task of an engine in a large tank is a very severe one. Our Army had, however, a goodly number of tanks

in operation for a considerable time during the war and these were right at the front when the Armistice was signed. The tanks are not an independent arm of the service in that they require infantry support. One of their particular functions is to clear the way for the infantry, especially with regard to enemy machine guns. There is no doubt that the tanks are a decidedly effective humane element in the saving of men in war engagement.

A. R.

Suez Canal Business During the War Period.—While the international agreement under which the Suez Canal is operated prohibits its being blockaded, the state of war influenced materially the traffic through it, particularly in view of the activity of the submarines of the Central Powers. As the German-Austrian surface navy was practically swept from the seas in the early days of war, it is probable that if submarine activity had not occurred but little difference would have been found in the canal traffic. The data for 1918 in comparison with those for 1912, for instance, show a falling off of over 50 per cent. in number of ships, and somewhat less than the same percentage in total tonnage. Notwithstanding the concentration of submarines on the English commerce, the canal traffic under the English flag was, during 1918, over 79 per cent. of the total. Throughout the years, England has led by a large margin, Germany being second. German tonnage, of course, disappeared, and that of Holland which was third in 1912 fell to a single ship of less than 5000 tons. The falling off of the Dutch tonnage is probably due to the diversion of the East India traffic to the Cape of Good Hope route for safety. Italy and Japan have increased somewhat their canal tonnage, but may not be able to hold their relative position when England recuperates. The United States tonnage is, as might be expected, quite small; for some recent years less than half a dozen ships a year, with a total tonnage of less than 10,000. Comparative statistics show that the average tonnage per vessel has been, as a rule, increasing.

H. L.

Starch-dust Explosions.—In some investigations of the phenomena of dust explosions at the plant of the Bureau of Mines near Pittsburgh, a very unexpected result was obtained. The plant consists of a steel cylinder, 225 feet long set above ground, intended as a counterpart of a mine gallery. The upper part of the pipe has at certain intervals, ports provided with lids. The progress of an explosion can be watched by the jets of flame and smoke that appear at the vents. Lately, motion pictures have been taken of the phenomena, more particularly for use in campaign for prevention of grain-dust explosions. After experiments with coal-dust, in which rather violent explosions were produced,

the cylinder was cleaned and flour-dust exploded. The blast was far more violent than that from the coal-dust, and startled the engineers. Starch-dust was then used.

During each of the first two blasts the operator was somewhat shaken by the detonation, but the shocks were relatively light and their effects little more than temporary. With the setting off of the starch charge, however, the earth seemed to tremble, the booth rocked on its foundation, and reports received later showed that houses two and three miles away were shaken. The concussion shattered the glass in the walls of the camera booth. The operator was temporarily blinded and almost stunned, but his long training in his profession kept him turning the crank of his camera even as it swayed to and fro in its shelter. All of this upheaval took but an instant of time. Climbing out from the broken booth the operator looked about and found that some of the engineers, who had stood at a considerable distance to witness the test, had been thrown to the ground. As soon as they recovered their senses and equilibrium they ran to the camera booth, fearing that the operator had been killed.

While no one received serious injuries, the experiment was one which no one is anxious to go through a second time. Examination of the Bureau of Mines' equipment showed that the concrete foundations had been shattered by the violence of the blast and part of the shelves within had been blown out and reduced to kindling, while the target or deflecting screen which stood at some distance from the open mouth of the cylinder, had been partly torn from its deeply laid foundations. Motion-picture men state that in the whole history of the industry, few movie views of this sort have been taken under such hazardous circumstances.

H. L.

De-lousing Experiments.—Every one knows the serious aspect of the louse question in army hygiene. While those who were far from the trenches were occasionally humorous about the "cooties," those who had to deal with them saw no joke. The subject has an industrial as well as military bearing, for the insect is known to be a carrier of several diseases. It is pretty well established that in Serbia typhus fever was mainly propagated by lice. Human beings are infected with three forms of lice, but the most important one is the body louse (*Pediculus corporis*). A scientific investigation of the methods of ridding clothing of these was undertaken by Wm. Moore, B.A., and Arthur D. Hirshfelder, M.D., both of the faculty of the University of Minnesota. The work is far from agreeable, but the investigators, with others, including students of the University, pursued faithfully their labors. Lice were reared in great numbers in incubators and fed on human blood, as many as 4000 having been fed at one time on the forearm of one person.

The pamphlet of 86 pages, 8vo., gives the details of the experiments, and an extensive bibliography. The conclusions are as follows:

1. Lice may be reared under incubator conditions in large numbers, if fed with human blood twice daily, but under such conditions the life cycle is slowed down, and the daily and total egg production per female is reduced.

2. Fever, rash, and a general lassitude are produced as a result of louse bites.

3. Lice and their eggs are destroyed by the ordinary laundering processes used in the washing of cotton and khaki goods; for woolens slight alterations in the methods of washing are necessary.

4. Chlorpicrin may be used for fumigation of garments, accomplishing the desired results in a short period, with a small quantity of the chemical, without the use of high temperatures.

5. The sachet method of controlling lice is ineffective or very expensive.

6. Louse powders may be used with success but, being a wasteful method of applying an insecticide, are not recommended.

7. Impregnation of the underwear is the most promising method of louse control between lousings. Active chemicals of very low volatility are necessary to prove effective for the longest period of time. Halogenated phenols, such as dibrometacresol, dichlormonobrometacresol, and their sodium salts, dibromcarvacrol, and dibromxylenol were found to be the most promising under laboratory conditions. H. L.

New Food Oil from Grape Seed. (*Am. Chem. Soc. News Service.*)—From the grape seeds is being derived a new food oil. It is pressed from the seeds which formerly were discarded. This by-product has been found edible and nutritious. It may become a rival of olive and cottonseed oils for cooking and salad dressing.

Dr. J. H. Shrader, of the Bureau of Plant Industry, of the U. S. Department of Agriculture, has made extensive investigations in the commercial utilization of grape seed. In a paper read before the Division of Industrial Chemists and Chemical Engineers, of the American Chemical Society, he suggested that all waste of this character from the vineyards and canneries be assembled at a centre, so that there will be enough tonnage to make its fabrication profitable. He said:

"In the grape-juice industry the grapes are pressed in ordinary cider presses to obtain the juice. The skins, seeds and pulp remain behind in the cloths. The total tonnage of grapes pressed for juice in the grape belts of New York, Ohio and Michigan was ascertained directly from the firms for each of the past five years in order to strike a fair average. From these figures a pomace yield of 20 per cent. was calculated, which in turn yielded one-quarter seed, one-quarter dry skins, and one-half water.

"A method has been worked out and operated in the laboratory on a semi-commercial scale whereby grape seed can be separated from wet grape pomace without recourse to drying. The seed separation will enable the producer to take out his seed from the balance of the waste at each pulping and pressing station. This makes him independent of the necessity of shipping all of his waste to the central plant."

Because of the shortness of the grape-juice pressing season, which lasts from September to November, estimates have been made on a plant only large enough to dry the maximum amount of seed and then press it in winter months. A charge of $9 per ton of raw material is allowed for drying and handling from freight cars to storage bins, while $15 to the ton of dry grape seed is allowed for expelling the oil and handling from the seed storage to the oil in tanks. This would include all overhead and management charges, except rent of property or interest on real estate investment.

Doctor Shrader believes that the efficiency of these plants could be increased by also extracting the oil from the seeds of tomatoes, as a great many such seeds are rejected in the making of catsup and in canning. Seeds from pumpkins and those from other vegetables can also be utilized.

Gas-masks for Ammonia.—Messrs. PERROTT, YABLICK and FIELDNER, of the Chemical Warfare Service (*J. Ind. Eng. Chem.*, vol. xi, 1919, 1015), describe a new form of gas-mask, especially adapted to the protection of workmen in industries in which refrigerating plants are operated. They point out that the usual method which employs pumice drenched with sulphuric acid has several objectionable features, among which are production of much heat by the absorption, high initial resistance, and the necessity for a canister capable of resisting corrosion. Caustic fumes are also produced which must be stopped by a pad, thus increasing the difficulty of breathing. They experimented with salts having the property of combining with ammonia, and give preference to pumice stone saturated with copper sulphate. This was shown to have a great capacity of absorption. A canister containing 45 cubic inches of this material will protect a man, breathing at rest, for five hours against an atmosphere containing 2 per cent. of ammonia and for two and one-half hours in an atmosphere containing 5 per cent. Tests at high breathing show that protection is ample at great exertion. Several other substances are efficacious, among which are cobalt chloride, boric and silicic acids. The copper sulphate method has the advantage of large capacity of absorption, low heat disengagement and cheapness.

In this connection, note should be made of a statement from the British Home Office (For. Ind. News, *J. Ind. Eng. Chem.*, vol. xi, 1919, 1064) that the ordinary army masks do not serve as

protection in dealing with mine fires, or entering the mine after explosions. The atmosphere in such cases contains a good deal of carbon monoxide, against which the ordinary charges of the mask are inert, and further, there is often a decided diminution of the proportion of oxygen, which may in itself be a great danger. Inasmuch as the masks protect against smoke, they give a feeling of security to a person entering the smoky air and thus add to the likelihood of his being overcome.

H. L.

Application of Fish-oils in the Paint Industry. (*Paint Mfrs. Assn. Circ.* No. 74.)—Several fish-oils have long been used in the manufacture of soap, leather and for hydrogenation. Tests have been made of four fish-oils—grayfish, shark, fur-seal and skate—with a view to determine if any of them can be used as drying oils, but the results were negative. Incidentally, it has been shown that, as regards these oils, at least, the iodine number is not an index of the drying qualities, for the fish-oils showed numbers from 135 to 151, but possessed much less drying power than some vegetable oils (soy bean and cottonseed), having figures as low as 120 to 130.

From a sample of shark liver oil a notable amount of an unsaturated hydrocarbon was extracted. The presence of this was indicated by the low saponification number and the large amount of unsaponifiable matter. The hydrocarbon was a pale yellow liquid without pronounced odor. A hydrocarbon of somewhat similar character was isolated a few years ago from the livers of species of sharks in Japanese waters by Mitsumaru Tsujimoto.

H. L.

A New Seed-oil. (*Paint Mfrs. Assn. Circ.* No 72.)—The oil from the seeds of *Calophyllum inophyllum*, a hardwood tree of the Philippines, known locally as Palo Maria, has been examined with a view to its applicability to the paint industry, but the results are not satisfactory, and it is evident that it must be subjected to some special treatment to give it rapid drying properties. The oil is not serviceable for food as it contains a poisonous resin, to which the color and odor are due. It is, however, used in its native regions as an application in skin affections. The fatty acids yielded by it are principally palmitic, oleic and stearic, so that it would serve well as a source of soap and glycerol.

H. L.

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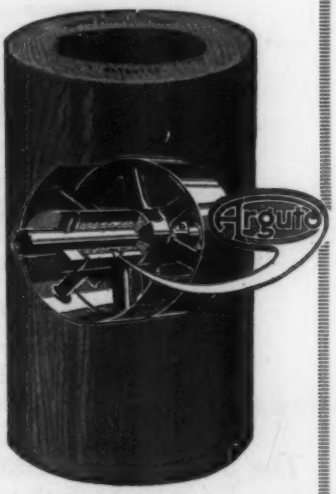

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